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THE FEBRUARY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

THE STUDY OF THE SKY IN EUROPE. DR. CLYDE FISHER 89
ADOLPHO LUTZ: A LEADER IN SOUTH AMERICAN MEDICINE AND BIOLOGY. DR. MAYNARD M. METCALF 112
THE ECOLOGY IN STEPHEN HALES' "VEGETABLE STATICKS." DR. HERBERT C. HANSON 115
DO BACTERIA HAVE DISEASE? PROFESSOR J. E. GREAVES 123
TACTUAL INTERPRETATION OF SPEECH. DR. ROBERT H. GAULT 126
THE INTELLIGENCE OF DELINQUENTS IN THE LIGHT OF RECENT RESEARCH. DR. MARGARET WOOSTER CURTI 132
EARTHQUAKES. COMMANDER N. H. HECK 139
PERPETUAL MOTION IN THE TWENTIETH CENTURY. DR. PAUL R. HEYL 143
THE PROBLEM OF ANEMIA. DR. ELLIS KELLERT 146
MODIFICATIONS DUE TO HUMAN AGENCIES IN THE MARINE LIFE OF THE PACIFIC COAST. DR. C. MCLEAN FRASER 151
RADIO TALKS ON SCIENCE:
Radio Transmission of Music. PROFESSOR DAYTON C. MILLER 158
Prophecy of a Chemist. DR. WILLIAM J. HALE 161
The Fixed Nitrogen Research Laboratory. DR. S. C. LIND 166
RELATIVITY AND LIFE. "BETA" 170
THE PROGRESS OF SCIENCE:
Dedication of the Peabody Museum of Natural History of Yale University; On the Nature of Bacteriophage; The Award of the Copley Medal to Professor Einstein; Dr. Cottrell and the Research Corporation; The Award of the Prize of the Research Corporation to Dr. Abel 173

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THE SCIENTIFIC MONTHLY

FEBRUARY 1926

THE STUDY OF THE SKY IN EUROPE

By Dr. CLYDE FISHER

AMERICAN MUSEUM OF NATURAL HISTORY

(All illustrations are from photographs by the writer)

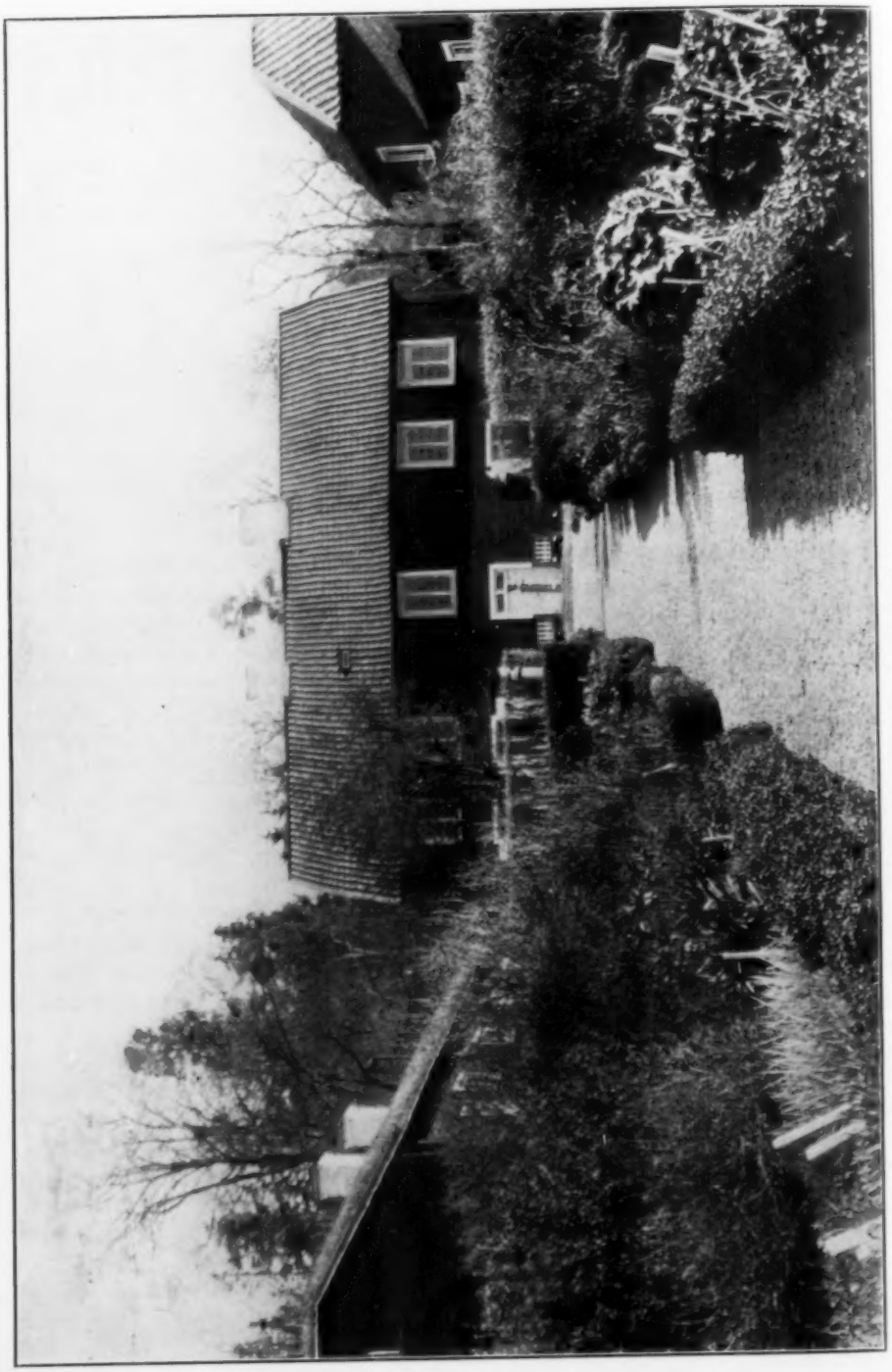
THE sun in the heavens by day and the ever-changing moon by night, the wandering planets and the scintillating stars in the night sky all engrossed the attention of man before the dawn of history, and these objects continue to absorb our interest even in this day of highly organized and complex civilization. Witness the millions of persons who turned out on an extremely cold winter day in January, 1925, to observe the awe-inspiring total eclipse of the sun! And note the innumerable amateur efforts to make photographic and other records of this rare occurrence! This is probably even more significant than the wonderful work of the professional astronomers.

In Europe more has been done and more is being done to keep alive this interest and to give it opportunity to grow than in America. In planning the proposed astronomical hall which is to be built at the American Museum of Natural History, it seemed advisable to make a survey of the methods and apparatus used in some of the countries of the old world. In pursuance of this idea, I was sent abroad in the summer of 1925 by the American Museum to make this investigation. Having the bent of an all-round naturalist, of course many things other than astronomical came in for observation. On this journey I was accompanied by my wife, whose interest and enthusiasm were as great as my own.

Going first to Sweden, I had opportunity to revisit places first seen on the American Museum expedition to Lapland in 1924, and to renew pleasant acquaintances made at that time. Here is an old civilization much more uniform and homogeneous than that of our own country. There are comparatively few persons of foreign birth or extraction in Sweden. After traveling over a good part of the country in 1924, during which time the only negroes I saw were in a variety show at the capital, I said to a Swedish gentleman, "You have no negroes in Sweden?" and he replied, "Oh, yes, we have. There are two in Stockholm and one of the mail-carriers is a mulatto."

More than ninety-nine per cent. of the people belong to the state (Lutheran) church of the country. Their schools are more highly developed than ours although not so flexible. One result of their system of schools is the remarkable fact that in all Sweden there is less than one per cent. of illiteracy.

The two complete universities, the one at Lund and the one at Upsala, were visited on my previous trip, and in 1925



HAMMARBY, THE SUMMER HOME OF LINNÆUS, NEAR UPSALA, SWEDEN. BOTH THE HOUSE AND THE GARDEN ARE KEPT AS THEY WERE IN THE EIGHTEENTH CENTURY WHEN PRESIDED OVER BY THE GREAT SWEDISH BOTANIST.

HAMMARBY, THE SUMMER HOME OF LINNÆUS, NEAR UPSALA, SWEDEN. BOTH THE HOUSE AND THE GARDEN ARE KEPT AS THEY WERE IN THE EIGHTEENTH CENTURY WHEN PRESIDED OVER BY THE GREAT SWEDISH BOTANIST.

DR. AND MRS. CLYDE FISHER EXAMINING AN EDIBLE SNAIL PICKED UP AT HAMMARBY, THE SUMMER HOME OF LINNÆUS, NEAR UPSALA. EDIBLE SNAILS WERE INTRODUCED AT HAMMARBY IN THE EIGHTEENTH CENTURY BY LINNÆUS.

ASTRONOMICAL OBSERVATORY IN STOCKHOLM.

I again went to Upsala, and upon recalling the fact that the university there was founded in 1477—before Columbus discovered America—I felt that American institutions are indeed quite youthful.

At the University of Upsala, I went to see the herbarium in the department of botany. Since I had in years gone by been interested in mushrooms, puff-balls and other fungi, I wanted to see some specimens actually collected by Elias Fries, who was one of the early authorities on the subject. By the way, he is the first of three generations of the Fries family who have been professors of botany in this great university. He was followed by a son, and at the present time one of his grandsons is professor of botany in this historic institution. It was a pleasure to find specimens collected by the elder Fries in good state of preservation. I met several botanists at Upsala, among them Dr. Nils E. Svedelins, the great authority on algae.

No naturalist traveling in Sweden would fail to make a pilgrimage to Hammarby, the summer home of Linnæus, the father of modern botany, who is without doubt the most widely known botanist who has ever lived. Not only is he known to every botanist in the civilized world, but to every zoologist and to every student of the biological sciences, as well. We were conducted on this trip by Dr. E. Einar Du Rietz, associate professor of botany at Upsala. In 1924 I had climbed Mount Nuolja in Arctic Lapland with Dr. Du Rietz, and profited by his thorough knowledge of the plant life of that region.

The house at Hammarby is painted red with white trimmings, as nearly all the cottages (*stugor*) are in Sweden. The garden is kept as Linnæus kept it in the eighteenth century. Back of the house is a little fire-proof museum which contains many books which belonged to Linnæus and many other things con-

nected with his life including the lecture-seat he used when professor of botany at the University of Upsala.

In the village of Upsala is the Linnæan botanical garden, kept as it was during the time of Linnæus. Near this garden is a museum of considerable size devoted to Linnæana.

By the way, the second one of the Fries line of botanists, Theodor Magnus Fries, has given us the best biography of Linnæus, and this has been used as source material for the recent Life in English by Dr. B. Daydon Jackson, secretary of the Linnæan Society of London. When in London later I called on Dr. Jackson at Burlington House in Piccadilly, and among other things examined, in the original herbarium of Linnæus, specimens of his favorite flower, *Linnæa borealis*, which he had collected in Lapland in 1732, the flower having later been named for him. I also handled and examined the original diary kept by Linnæus on his journey through Lapland. This was written in ink and was copiously illustrated with pen sketches of the Lapps and practically everything connected with their culture. It is a matter of surprise to outsiders, as it must be of chagrin to the Swedes, that these valuable Linnæana are not in his native country, but in London.

Due, no doubt, largely to the influence of Linnæus, the subject of botany is emphasized much more in the schools of

ASTRONOMICAL OBSERVATORY AT UPSALA. DR. BERTIL LINDBLAD, ASTRONOMER, IN THE FOREGROUND.

DR. EINAR LÖNNBERG, CURATOR OF VERTEBRATES, IN THE GREATEST NATURAL HISTORY MUSEUM IN SWEDEN.

Sweden than in America. It is a common sight in Sweden to see groups of boys and girls with the characteristic tin vasculums or collecting cases on botanical excursions. A large portion of their holidays and vacation is spent in collecting, mounting and identifying plants.

I found the astronomical observatory at Upsala well equipped for teaching purposes as well as for other serious work in this field. Dr. Bertil Lindblad, astronomer, who showed me their equipment, had studied at our Mt. Wilson Observatory. He recommended that I visit the uranias of central Europe, in view of our projected Astronomical Hall at the American Museum.

The State Museum of Natural History (*Riksmuséet, Naturhistoriska*) is the greatest institution of this kind in Sweden and is housed in a fine modern building. Dr. Einar-Lönnberg, curator of vertebrates, showed me through the department of mammals and birds. Quite unique is one room containing a historical collection of animals, some three

DR. NILS SVEDELIUS, PROFESSOR OF BOTANY IN THE UNIVERSITY OF UPSALA, AND WORLD AUTHORITY ON ALGAE.

hundred in number, all having been mounted more than one hundred years ago. Some of the taxidermy is astonishingly crude, while some of it is surprisingly good. Some of the extinct animals included are a quagga, a blue-buck, a Cape buffalo of an extinct variety and a warthog of an extinct variety—all from Africa. Besides these there were several species which are on the verge of extinction.

Another hobby of Professor Lönnberg's was the most complete collection of young mammals that I have ever seen. These are mounted with adults in family groups. Baby animals are always appealing.

There is a large collection of whales and other *Cetacea* here which includes a gray whale. I believe that, with the two specimens of gray whale obtained for the American Museum by Roy Chapman Andrews, are the only complete skeletons in the world. Professor Lönnberg also has three skeletons of the extremely rare sea-otter. Professor Lönnberg has done for the birds of Sweden what Chapman has done for the birds of eastern North America. I used his handbook in Lapland.

In 1924, after my return from Lapland, I visited Skansen, the unique out-of-door museum in Stockholm, with this mammalogist and ornithologist. Here is a fine collection of living animals native to Sweden, including a part of the largest herd of European bison in the world; a pair of Swedish moose, which resemble the American species, but have smaller antlers; three hybrids between the gray wolf and the domestic dog, and the three species of seals to be found in the waters bordering on Sweden.

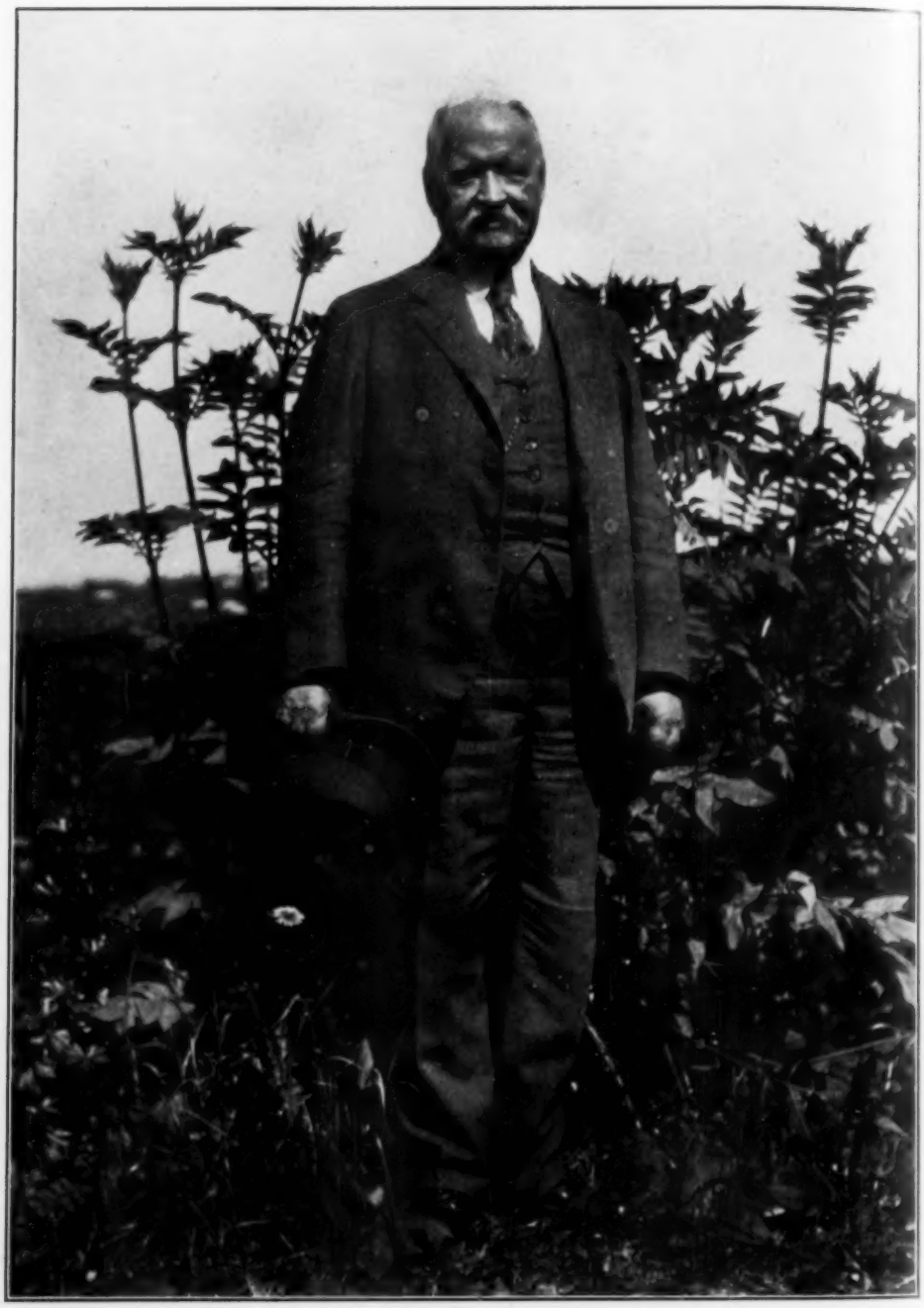
At the Nobel Institute we called on Professor Svante Arrhenius, the great chemist. He did not seem weighed down by his four different kinds of doctorate degrees. He is a most genial and lovable man.

Baron and Baroness Gerard DeGeer, companion geologists, showed us their method of counting time back to the glacial epoch by means of laminated clays. This is a great contribution to science, and the results have been completed for Scandinavia, and Professor DeGeer's students are now working in Canada and other parts of North America, and have already connected up a great deal of American post-glacial time with that of Scandinavia.

Sweden is a country of great beauty, and its people are so courteous and hospitable, and so genuine with it all, that it is difficult to leave the country. But our hurried schedule made it necessary for us to make our departure, and this we did through Malmö in the south, paying a short call to Denmark on the way down to Germany.

In Copenhagen we saw the astronomical observatory and learned that the director had seen the Zeiss Projection Planetarium in Munich and that he was most favorably impressed with it, a fact of significance to me because this planetarium was the principal objective point of my trip. In this city we visited Thorwaldsen's Museum of Sculpture and the Ny Carlsberg Glyptotek. I was more impressed with the beauty of the sculpture in the latter than that of any other gallery in Europe. Sinding's "Idyl" and "Natten" are particularly beautiful.

The first place we stopped in Germany was Hamburg, not for the purpose of visiting the astronomical observatory, for there is a good one in this city, but to see Carl Hagenbeck's Zoological Park (*Tierpark*) in Stellingen just outside of Hamburg. The striking thing about this "zoo" is the commodious and realistic installations of the animals. The inclosures are bounded by deep and broad and more or less hidden trenches, and one may see lions, polar bears, reindeer and other animals in their natural habi-



PROFESSOR SVANTE ARRHENIUS, FOUNDER OF THE ELECTROLYTICAL DISSOCIATION THEORY, WHICH IS THE BASIS OF MODERN ELECTRO-CHEMISTRY, PHOTOGRAPHED AT THE NOBEL INSTITUTE.

DR. KARL E. VON GOEBEL, DIRECTOR OF THE BOTANICAL GARDEN IN MUNICH, AND PROFESSOR OF BOTANY IN THE UNIVERSITY OF MUNICH, PHOTOGRAPHED IN THE BOTANICAL GARDEN.

GOETHE'S "GARTENHAUS" IN WEIMAR.

tat realistically reproduced, with no bars between the animals and the observer.

From Hamburg we went to Berlin by an express train equipped with wireless telephone, the first I had ever seen on a railway train. Upon inquiry I learned that this had been installed only about two months before, and that this was the only place in Germany where the experiment was being tried.

In Berlin we saw the specimen of *Archaeopteryx*, at the Natural History Museum. This is the oldest known bird, having lived millions of years ago. It is about the size of a crow, and had teeth, which are not found in any living birds. Only two specimens of the *Archaeopteryx* are known, and both of these were found in the Solenhofen lithographic stone in Germany. One specimen is in Berlin as noted above, and the other is in the British Museum of Natural History at South Kensington, where I saw it in 1924 and again later in the fall of 1925. The Berlin specimen, however, is the better. The teeth are quite distinct, the feather impressions are more perfect and the bones are wonderfully preserved. We were surprised to find that only a cast is on exhibition in the Berlin Museum. The real specimen was shown to us by Dr. Reck, curator of geology. Since it was not on exhibition, I expected to find that the precious specimen was locked up in a fire-proof safe, but not so; it was kept in the drawer of a wooden desk used by an assistant. I am sure we should take better care of it at the American Museum of Natural History.

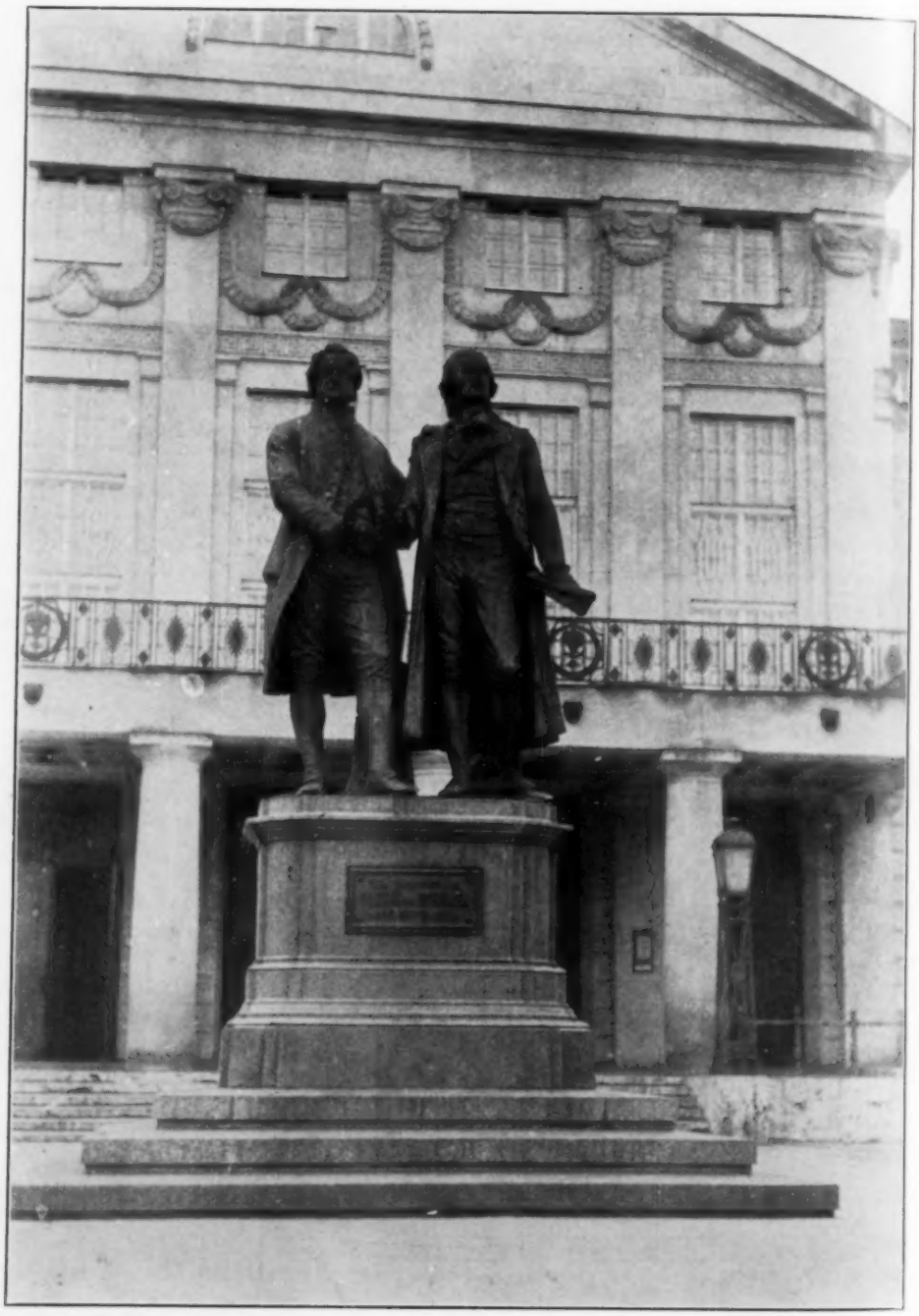
Dr. Reck also showed us some of the remarkable dinosaur remains found in Africa by the Tendaguru Expedition, for example, the only example of *Kentrurosaurus* in any museum in the world, and parts of the tremendous *Brachiosaurus*, the largest dinosaur known.

Among the habitat groups of animals was one of the beaver, which was just being made. It is to be a moonlight group, an excellent idea for an animal that is mainly nocturnal in its habits. It reminded me of a night group in the Upsala (Sweden) Biological Museum, showing a family of badgers prowling for food, and above in the trees we see how some birds spend the night, a number asleep and some awake and active, as the owl and the goatsucker. The same idea is also beautifully illustrated by the group of timber wolves on the trail in the American Museum of Natural History.

At Potsdam we visited the Royal (as it was formerly called) Astrophysical Observatory, where I examined especially their new Einstein Tower, the second one to be constructed. It is believed to be an improvement over the one at the Mount Wilson Observatory, which was the first one to be built. With this equipment the Einstein theory will be tested by measuring the displacement of the Fraunhofer lines, the spectrograph connected with this tower being very much more efficient than that connected with any refracting or reflecting telescope. The spectrum is spread out in a large room, which no one enters, and which is kept at a temperature constant to one hundredth of a degree.

In Jena we stopped at a hotel just across the street from the University of Jena, where Ernst Haeckel was professor of natural history for more than forty years. He was one of the early champions of Darwin. Schiller was also a professor here for a time.

My object in coming to Jena was to examine the newly invented projection planetarium made by the Carl Zeiss Optical Works. Several days were spent in studying this piece of apparatus, every facility having been given and every courtesy shown. Beneath a hemispherical dome, large enough to accommodate two hundred and eighty persons in this



STATUES OF GOETHE AND SCHILLER IN FRONT OF THE NATIONAL THEATER IN WEIMAR. IT WAS IN THE NATIONAL THEATER THAT THE GERMAN REPUBLIC WAS FORMED.

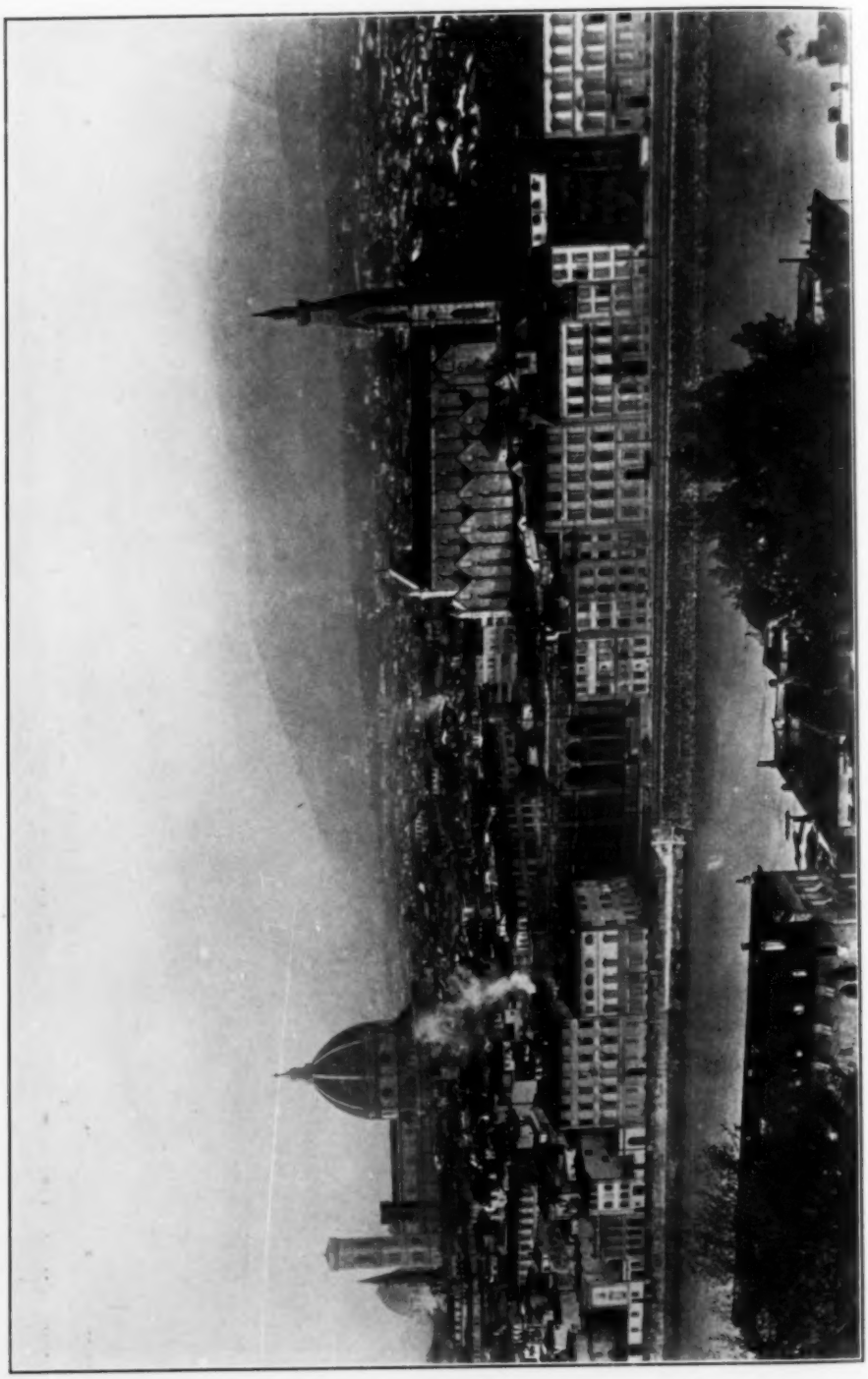
TOMBS OF BEETHOVEN AND OF SCHUBERT, IN VIENNA. ADJOINING IS A CHILDREN'S PLAY-GROUND CALLED SCHUBERT PARK. WHAT AN UNUSUAL CEMETERY! AND HOW APPROPRIATE FOR THIS COMPOSER OF SONGS!

case, is a projection machine, a kind of a glorified, animated stereopticon, by means of which is shown on the inside of the dome, the sun, the moon, all the planets visible to the naked eye, and the four thousand five hundred fixed stars that are visible to the unaided eye, including the Milky Way. These projected images move as the real bodies appear to move in the sky, with the time accelerated, due to rotation of parts of the central apparatus, which has been made and geared with such great precision that it runs with extreme accuracy. Since it is the writer's intention to prepare a special article on the planetarium, we shall not go into details here. It may be sufficient here to state that the demonstration of this apparatus had been so impressive that at the time of my visit to the Zeiss works in early September, there had already been sold eleven to German cities alone. The representation of the night sky is so realistic, the rotation of the earth on its axis is so convincing, the erratic motion of the planets is so well shown, not to mention many other phenomena which are demonstrated, that the study and appreciation of astronomy will be given great stimulus among children and laymen who have opportunity to see this planetarium in action.

At the Zeiss Works we were also interested to go through the astronomical

MT. WETTERHORN IN THE CLOUDS FROM BRÜNIG. THE BEAUTY OF THE SCENERY IN THE ALPS SURPASSED OUR EXPECTATIONS. PHOTOGRAPHS OF THE ALPS ARE FAMILIAR TO ALL, BUT THE REALITY IS MUCH MORE IMPRESSIVE.

THE ALPS FROM INTERLAKEN. IN LATE SEPTEMBER, FRESHLY FALLEN SNOW COULD BE SEEN ON THE EVERGREEN TREES IN THE HIGHER PARTS OF THE MOUNTAINS, A BEAUTIFUL SIGHT IN THE BRIGHT SUN.



FLORENCE, FROM MICHAEL ANGELO'S PLACE, SHOWING THE CATHEDRAL AND THE CAMPANILE ON THE LEFT, AND ST. CROCE CHURCH ON THE RIGHT.

part of the plant, and to watch the building of telescopes and mountings. At another place I had my first look through an ultra-microscope by means of which I saw in a clear solution dancing particles of silver less than one millionth of a millimeter in diameter. Of course these would be absolutely invisible in an ordinary compound microscope with an oil-immersion lens of the highest power.

The Zeiss Works is a donation, as the Germans call it, to the people made by Ernst Abbe, inventor of the Abbe condenser, at that time the sole owner. He was too modest to allow his name to be used in the name of the concern, but instead used the name of the founder, Carl Zeiss. It is a cooperative organization, and all the profits go to schools and other philanthropic purposes. The scientists and technical workers are employed for life. On the staff are fifty pure scientists, not counting engineers and technical men. In the glass works, Schott, the famous expert in optical glass, although past eighty years of age, is still working every day.

From Jena we went to Weimar, thirteen kilometers distant, where Goethe lived the last fifty-six years of his life, and where also lived Schiller, Liszt, Wieland and Herder.

Goethe's Gartenhaus and his old home are preserved and open to pilgrims. Both are now shrines where many come. The old home is a veritable Goethe Museum. Here one may see his workrooms, bedroom, original library, various collections and laboratories, all kept as this great master used to keep them.

The Schillerhaus is a much more modest dwelling. Goethe inherited much wealth from his parents, while Schiller's parents were poor. Schiller's old home is now a museum, a shrine also visited by many pilgrims. Goethe's and Schiller's tombs are side by side in an old cemetery on the edge of Weimar.

The Liszthaus is a museum kept in the same way. We were interested in the room in which he gave piano lessons, always without pay. Two or three of his pianos are in the old home, as well as a spinet upon which he got finger-practice.

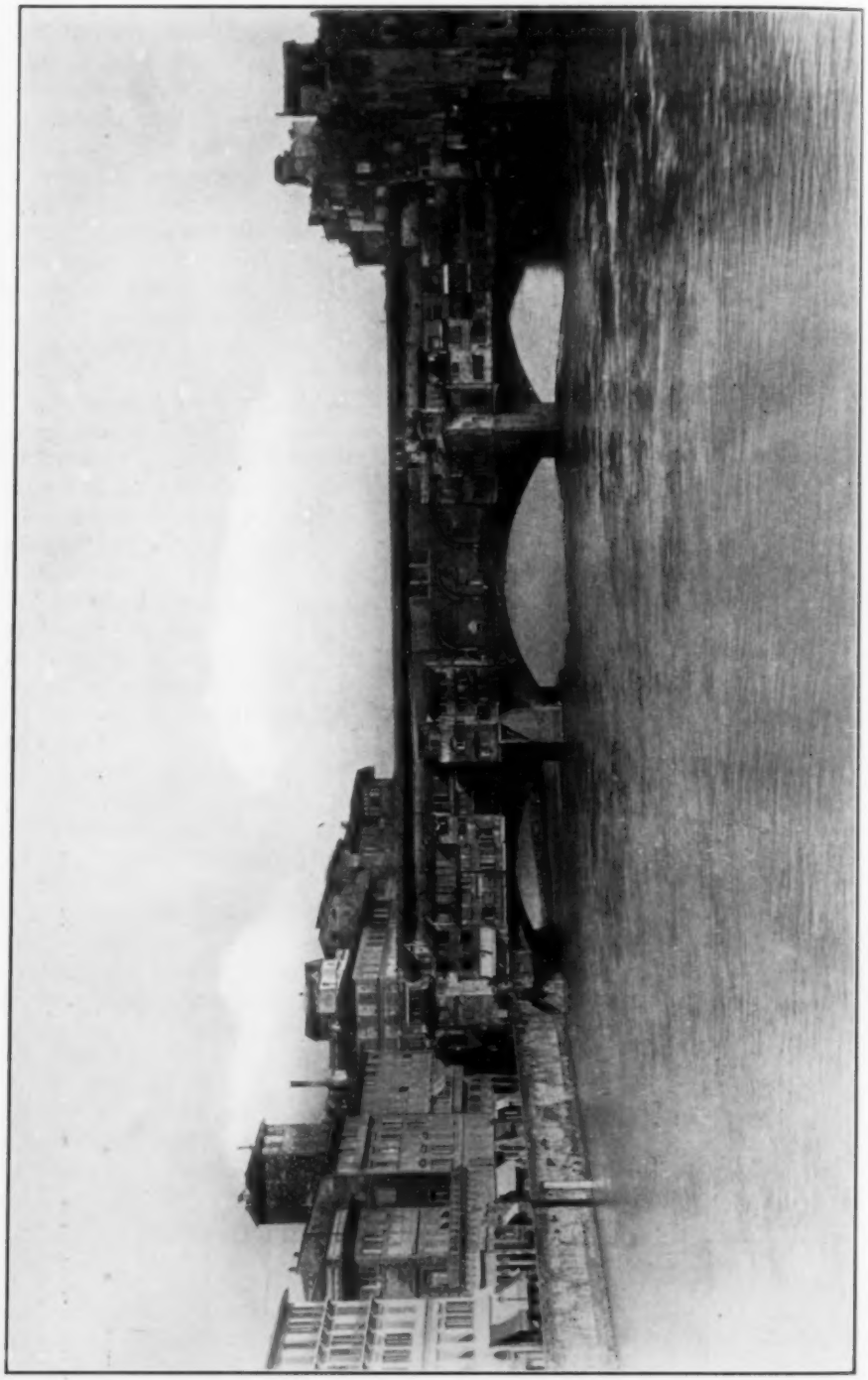
On the way from Jena to Dresden, we changed trains at Leipzig in the largest railway station in Europe. In Dresden we visited the famous collection of paintings, said to be the finest north of Italy. Raphael's *Sistine Madonna* and many others attracted our attention, to say nothing of the great collection of sculpture, the Green Vault, and the collection of porcelain.

At Munich our chief interest was in the great German Museum, and in the department of astronomy of that institution. We were unfortunate in missing the president, Dr. Oskar von Miller, on account of his absence in America, but we carefully examined the astronomical exhibits, which on the whole do not have a rival anywhere. Indeed it probably would not be far from the truth to say that the astronomical exhibits of the German Museum excel all the rest of such collections in the world. More than twenty-five rooms, halls, terraces and domes are devoted to astronomy.

In one room is a large Ptolemaic planetarium in a spherical glass globe about six feet in diameter, with the principal constellations painted in their proper relative positions on the glass sphere. As it was understood in the Ptolemaic system of astronomy, the earth is stationary at the center of the apparatus, and the Sun, the Moon and the planets that were known when this theory prevailed revolve around the earth, each planet upon its epicycle. There is a crank on the outside of the sphere with which visitors may turn the whole apparatus. It is an excellent mechanism.

In another room is a Copernican planetarium of the same size, with the constellations on the glass sphere, and in accordance with this, the present-day theory of the solar system, the sun is at the center, and the eight planets with

FLORENCE, FROM MICHAEL ANGELO'S PLACE, SHOWING THE CATHEDRAL AND THE CAMPANILE ON THE LEFT, AND ST. CROCE CHURCH ON THE RIGHT.



BRIDGE (*Ponte Vecchio*) OVER THE ARNO RIVER IN FLORENCE, BUILT IN 1362. THERE ARE MANY QUAINT SHOPS ON THE BRIDGE.

Principal Dome of the Vatican Astronomical Observatory in the Pope's Garden, Rome.

their satellites, all geared properly, revolve around the central sun. There is a crank on the outside of the glass sphere for turning the whole apparatus. This is another excellent mechanism.

The feature of a crank on the outside of these pieces of apparatus, which can be turned by the visitor, adds greatly to his interest and understanding. A similar crank was to be found attached to a device for showing the phases of the moon.

In another large room is a very large Copernican planetarium, made by Carl Zeiss. A lighted globe in the center represents the sun. The six planets nearest the sun, with their satellites—the planets and satellites all revolving at their proper relative speeds—are shown. The diameter of Saturn's orbit is about forty feet. Uranus and Neptune are left out, I presume, because their tremendous distances would make the rest so small proportionately. There is no light except from the central sun, and the walls, ceiling and floor are painted black. Consequently, day and night are well shown on any of the six planets, and so are the phases of our moon. For the lecturer or demonstrator, a car travels around under the earth, which goes around the sun in twelve minutes, the apparatus being propelled by an electric motor. The phases of Venus and Mercury can easily be observed. The constellations of the Zodiac are shown in a belt on the wall, with their names in white letters, and with the degrees of the circle marked. The stars are shown by lights back of small, round holes in the black wall.

In one room, more than one hundred kinds of sun-dials were exhibited, and on an adjoining terrace the four principal types of sun-dials were set up for ac-

Bridge (*Ponte Vecchio*) over the Arno River in Florence, built in 1362. There are many quaint shops on the bridge.

ORIGINAL TELESCOPES OF GALILEO IN THE MUSEUM OF PHYSICS IN FLORENCE. WITH THESE GALILEO WAS THE FIRST TO SEE THE SPOTS ON THE SUN, THE PHASES OF VENUS, THE RING OF SATURN, THE MOUNTAINS ON THE MOON AND THE SATELLITES OF JUPITER.

tual service out of doors. On clear days these attracted the attention of visitors.

The evolution of the refracting and reflecting telescopes is shown in another room, illustrated for the most part by real telescopes. Galileo's original telescope is shown in replica only. However, the original telescope of Simon Marius, with which he saw the moons of Jupiter in 1610, the latter part of the same year in which Galileo first saw them, is here. In this room are four original astronomical instruments of Tycho Brahe.

One of the new Zeiss projection plane-

GALILEO'S TOWER NEAR FLORENCE.

tariums is installed in a dome here, and is easily the most popular piece of apparatus in the whole astronomical department. There are two lecturers who together give nine demonstrations a day. We attended one of these, at which a part of the audience was made up of a large class of pupils from a parochial school accompanied by two or three sisters.

While in Munich I called on Professor Dr. Karl E. von Goebel, the great botanist, at the botanical garden, and found with him Professor Dr. G. Haberlandt, from Berlin, who is perhaps the greatest authority on plant anatomy. It was thrilling to see these men, both of whose books I had used when a student in Johns Hopkins University.

At Vienna, in the Natural History Museum, I examined the collection of meteorites, which is said to be the finest in the world. The excellence and diversified nature of the specimens was evident.

At Vienna I also visited the Urania, which is a popular observatory in which the people may, for a small fee, observe on any clear night celestial objects through a fair-sized telescope. These observations are aided and directed by a trained person who explains what is seen. When the sky is clear enough for observation, a red light is shown on the Urania building. Usually two lectures with observations are given each evening, one rather early (eight to nine o'clock) and one rather late (ten-thirty to eleven-thirty). On the day I visited the Vienna Urania, there was a large sign at the door, stating that if the sky was clear on that night, the following objects could be satisfactorily seen: Jupiter, Uranus,

ST. PETER'S AND PART OF THE CITY OF ROME, AS SEEN FROM TOP OF DOME OF VATICAN ASTRONOMICAL OBSERVATORY

the star cluster in Perseus, and the great nebula in Andromeda. The Urania is also open during certain hours of the day for the observation of sun-spots with the astronomical telescope, and for the viewing of mountains and other distant objects with the terrestrial telescope. Later I also visited the Urania in Zürich, Switzerland.

In Rome we found an excellent observatory in the Pope's Gardens. The director, Father J. G. Hagen, is a naturalized American citizen. Taking a real interest in our proposed astronomical hall, he strongly advised the installation of a small telescope which could actually be used by visitors for viewing objects in the sky. In the Vatican Observatory we were surprised to find a little museum of astronomy, in which some of the constellations are marked on the dome ceiling of the single room. The Pole star and the stars of the Big Dipper are marked by electric lights, which when turned on illustrate very clearly how to locate the north star by means of the "pointers."

At a little *trattoria* in *Via Della Scrofa*, our waiter showed us a copy of Sinclair Lewis's "Babbitt," calling our

attention to a reference to this *trattoria*, where one can get "the best *fettuccine* in the world," a sufficient reason for going to Europe.

We spent several days in an attempt to see the Eternal City, but lack of space precludes further description.

In Florence, we visited the Astronomical Observatory and Galileo's Tower, and in the museum of physics I was greatly interested to see the two original telescopes of Galileo, with which he first saw the moons of Jupiter, the ring of Saturn, the spots on the sun and the mountains on the Moon and Venus as a waxing and waning crescent. The photograph of these telescopes was of necessity made under poor light conditions and from an unfortunate angle.

The beautiful objects of art in the Uffizi Gallery and in the Pitti Palace must at least be mentioned. The Campanile, "the most marvelous bell-tower in the world," attracted our attention, as for different reasons did the old homes of Benvenuto Cellini, Dante, Amerigo Vespucci and Galileo.

In the Paris Observatory, I found our own astronomer, George W. Ritchey, who made the one-hundred-inch disc for the big reflector at Mount Wilson. In the observatory building he is attempting to make much larger discs than ever have been made before, and on an entirely new principle. His new discs are of glass, but they are not solid. Each disc is made of many pieces in such a way that the completed disc is much lighter than the old solid disc, and it is ventilated, so that it responds more quickly and more evenly to changes in temperature.

The Paris Observatory is famous for its astronomical records, especially those dating back to the early days. It is also famous for its International Time Department, which I visited, every instrument having been demonstrated for me. Here I saw permanent records being made of radio signals from Annapolis.

One could not miss the Louvre with the "Venus de Milo," the "Winged Victory" and the "Mona Lisa," and all the rest of the beautiful things there.

In the Science Museum at South Kensington, London, is an astronomical department, but not nearly so large or so interesting as that of the German Museum in Munich. However, one should mention two telescopes made and used by Sir William Herschel, as well as a number of other pieces of apparatus used by the Herschels. The first permanent photographic negative ever produced is here. It is a photograph of the forty-foot reflector at Slough and was made in 1839 by Sir John Herschel. A print from this negative is framed from rungs of the ladder of the mounting of Herschel's forty-foot reflector at Slough.

It is hoped that much valuable data for use in planning and equipping the new astronomical hall at the American Museum of Natural History has been gathered on this trip. The reasons why it is felt that one of the Zeiss projection planetariums should be a part of the equipment will be given in a subsequent article.

HILLS COVERED WITH OLIVE-TREES, NEAR FLORENCE.

ADOLPHO LUTZ

ADOLPHO LUTZ: A LEADER IN SOUTH AMERICAN MEDICINE AND BIOLOGY

By Dr. MAYNARD M. METCALF
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DR. ADOLPHO LUTZ, of Brazil, has had the experience of seeing during his lifetime a complete change in the public and the medical attitude in his country toward work in public health and preventive medicine, a change from bitter and even personally menacing opposition to one of full and enthusiastic acceptance. When, as director of the Bacteriological Institute at São Paulo, he introduced into South America vaccination, isolation and regional quarantine methods against smallpox and typhoid and yellow fever epidemics he had much more opposition than support from his fellow physicians, and the people in at least one quarantined city threatened his life. The contrast in the personal feeling was shown last year at the Brazilian Congress of Hygiene which gave him a rousing ovation when he entered the hall. But the many years between had been full of strenuous and devoted work.

The great medical and biological research station at Rio de Janeiro—The Oswaldo Cruz Institute—plans to celebrate the seventieth anniversary of his birth, which occurs on December 18 of this year, and, as he is out of the country for a time on a government mission in Venezuela, his own modesty can not well prevent carrying the plans to fulfillment.

A few words of description of the accomplishments of this most outstanding Latin-American scientist may be of general interest.

Born in Rio de Janeiro of Swiss parents, he studied in Berne, London (with Lister), Vienna, Prague, Leipzig (with Leuckart) and Hamburg (with Usena in dermatology). His first scientific paper was published at the age of twenty-three, and since that time he has put out more than one hundred and seventy-five contributions. His earlier studies and publications were in the fields of dermatology and parasitology, in both of which he is still at work.

Returning from his European studies to Brazil in 1881, he took up the practice of medicine in the state of São Paulo, writing during this period several papers upon hookworm.

A few years later, when Professor Usena, of Hamburg, was unable to accept a call to go to the leper colony in the Hawaiian Islands, he recommended Dr. Lutz, who went there and was in residence at the colony for several years. Here he met the devoted English volunteer nurse among the lepers, who later became his wife. Professor Lutz has written much upon leprosy. He was the first to describe granulation in acid-fast bacilli, observing the phenomena in connection with leprosy. He believes in the carriage of leprosy by mosquitoes during those phases of the disease when the bacilli are in the blood stream. He thinks it possible that some other Diptera, but not fleas or lice, may carry the contagion. During this Hawaiian residence he wrote important papers upon rhinoscleroma and other parasitic diseases of the skin.

After his return to Brazil in 1892 appeared papers upon *Ascarics* and *Fasciola hepatica*. It was at this time that he was appointed director of the Bacteriological Institute in São Paulo and at once began his work in public

health. He was the first to identify "São Paulo fever" with typhoid. Stimulated by an epidemic of yellow fever, he met the emergency and was the first to follow in another country the prophylaxis methods so successfully used by Gorgas in Cuba in combatting this scourge, methods which since have been applied to all tropical America—thanks chiefly to the International Health Board—and which bid fair to exterminate ultimately this disease. Finding among the Paulista physicians much opposition to these then new ideas of mosquito carriage of yellow fever contagion, he with two other physicians and three laymen slept in beds and bedding which yellow fever patients had used—with, of course, negative results, and to clinch the matter in the minds of his medical colleagues, he allowed himself to be bitten by an infected mosquito, but fortunately for the state of São Paulo and all Brazil he did not contract the disease.

During this period of service as public-health officer he traveled throughout the state, inspecting conditions, especially where there was outbreak of communicable disease. It was at this time that he met the bitter opposition already mentioned, his methods being regarded as over-strenuous and his regulations as overstrict. When in the year 1900 a serious epidemic of bubonic plague broke out, he found so little help that he worked almost singlehanded, making autopsies and culturing the bacteria, as well as making the fight against the disease and its rodent carriers.

The contrast now in Brazil is most remarkable. No country is more strict in enforcing vaccination. In Rio de Janeiro and in other Brazilian cities there is inspection of all premises by a public health inspector every two or three weeks to guard against malaria and yellow fever mosquitoes and to prevent conditions favorable to typhoid fever or other diseases of bad sanitation. The effectiveness of his work, shown by the elimination of diseases formerly rampant, finally changed both medical and public sentiment, and when, after twenty years of service in the Department of Public Health, he left São Paulo to accept a call to the new research institute at Rio de Janeiro, the state of São Paulo commemorated his devoted service by a medal struck in his honor.

His São Paulo period is marked by publications, among others, upon malaria and its carriage by mosquitoes; upon malaria mosquitoes breeding in the water in *Bromilia* leaf cups in tropical forests where there are no breeding ponds or swamps; upon Haemogregarines of snakes; upon many new blood Sporozoa of birds; upon Microsporidia, many new species; and upon Trypanosome infection of cattle in the Amazon region, which was causing most serious damage.

The period of work at the Oswaldo Cruz Institute in Rio de Janeiro shows many publications, among them monographs of several families of Diptera, and, more lately, studies of Trematodes, one of these being upon *Schizostoma mansoni*, a blood fluke; and he has now nearly ready for the press a beautifully illustrated monograph upon Brazilian Batrachians, including descriptions of some thirty new species.

He has been official delegate to many international medical and scientific congresses; has received numerous medals and decorations from South American and European governments; is foreign member of many societies; is honorary president of the Brazilian Dermatological Society; was honorary president of the American Congress upon Leprosy.

This modest man, with indefatigable scientific zeal, undaunted courage and indomitable will in case of need, has seen almost the beginnings of Latin-American productive science and is now an honored and beloved leader in a group which is giving to South America a worthy place in the world of scientific research.

THE ECOLOGY IN STEPHEN HALES' "VEGETABLE STATICKS"

By HERBERT C. HANSON

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STEPHEN HALES, according to Sachs, was "the last of the great naturalists who laid the foundations of vegetable physiology." The book, "Vegetable Staticks," was made up of papers presented before the Royal Society while Isaac Newton was president. It was endorsed by Newton and dedicated to George, Prince of Wales. The book attracted considerable attention, going through three English editions; the first in 1727, the second with amendments in 1731 and the third in 1738. A French translation by Buffon was printed in Paris in 1735, and a later revised edition by Sigaud dela Fond appeared in Paris in 1779. An Italian edition with annotations by Michel Angelo Ardinghelli was published at Naples in 1776. A German edition was published in Halle in 1748.

"Vegetable Staticks" shows the author's "genius of discovery and the sound original reasoning powers." Sachs says he was "penetrated with the spirit of Newton's age, which notwithstanding its strictly teleological and even theological conception of nature did endeavor to explain all the phenomena of life mechanically by the attraction and repulsion of material particles. Hales was not content with giving a clear idea of the phenomena of vegetation, but sought to trace them back to mechanico-physical laws as then understood." His immediate predecessors were Malpighi, Grew and Ray. Priestley was born in 1733, Ingenhousz in 1730. He occupied in respect to time an isolated position in physiology. While Hales was concerned primarily with the physiological aspects of the plant, his contributions to ecology were naïve and important.

I. ENVIRONMENTAL FACTORS

Rainfall-evaporation ratio: The annual rainfall at Teddington, England, was 22 inches and the evaporation from the soil surface 6.2 inches. Subtracting the evaporation from the rainfall left 15 inches to replenish the earth for vegetation and to supply springs and rivers. This was considered sufficient for all purposes in that flat country. In a certain hilly region the excess of the amount of rainfall over that of evaporation was still greater.

Dew: The dew was considered a very important factor. Hales reasoned that since it can not soak down into the soil to the roots before being evaporated the great benefit of it must occur in hot weather through its absorption by the above-ground parts. This would refresh the plants and furnish them with a fresh supply of moisture for transpirational losses. The beneficial effects of washing newly transplanted trees with water were thought to be due to absorption by the trees. It appears that the dew was considered valuable not only for the water imbibed but also on account of other properties contained in the dew, for he says that plants in "hot countries abound more with fine aromatick principles than the more northern plants, for they do undoubtedly imbibe more dew. . . . And if this conjecture be right,

FIGURE 1. FACSIMILE, NATURAL SIZE, OF FIGURES 1 AND 2 IN HALES'S "VEGETABLE STATICKS." TWO METHODS OF MEASURING TRANSPIRATION ARE SHOWN; THE SEALED CONTAINER IN WHICH THE ENTIRE PLANT IS GROWING, AND THE CUT-SHOOT POTOMETER.

then it gives us a farther reason, why trees which abound with moisture, either from too shaded a position, or a too luxurious state, are unfruitful, *viz.*, because, being in these cases more replete with moisture, they can not imbibe so strongly from the air, as others do, that great blessing the dew of Heaven" (p. 326–327). The better colors and odors of flowers in dry soil as compared with those in wet soil were explained as being caused by the greater absorption of dew in the dry soil.

At times, however, the dew was considered harmful, for when the gardeners put bell-glasses over their cauliflowers early on frosty mornings before the dew had evaporated the dew was raised within the containers by the sun's heat and formed a scalding vapor which burnt and killed the plants.

Snow: A snow cover was considered valuable in protecting the roots of winter grain from being frozen and the shoots from fading and turning yellow in the drying winds.

Moisture content of the soil: A cubic foot of soil from the surface, another from a foot below the surface, and a third from two feet below were taken from a "good brick earth." The wet weights were secured and the soil was then air-dried. The wet weight of the surface foot was 104 pounds 4 1/3 ounces, the second foot 106 pounds 6 1/3 ounces, and the third foot 111 1/3 pounds. The losses were 6 pounds 11 ounces, 10 pounds, and 8 pounds 8 ounces, respectively. These amounts were calculated to be sufficient to supply a sunflower plant for 21 days 6 hours, after which the plant would die unless rain fell or the soil below three feet were drawn upon.

Humidity: Hales noted that some diseases were more prevalent on plants, as hops, in moist air than in dry air; that growth was more rank in moist air and more fibrous and woody in dry air; and that dry air increased transpiration while moist air decreased it.

Thermometers, soil and air temperatures: Six thermometers were made with stems varying from 1.5 to 4 feet long and with a bulb at the base. These were graduated into 90 degrees, zero being the freezing point and the maximum was evidently the boiling point of water. The optimum temperature for most plants was given as 17 to 30 degrees. The common temperature at noon in July was about 50° in the sun and 17° in the shade. In a hot-bed composed of horse manure temperatures of 75°, or more, were observed.

Readings at various times of the year were made in the air and at five depths in the soil. In August, at noon, the air temperature was 48°, in the soil at 2 inches it was 45°, at 16 inches 33°, at 24 inches 31°. In the latter part of October the air temperature was 3°, at 2 inches in the soil it was 10°, at 16 inches 14°, and at 24 inches 16°. In the first part of November it was 4° in the air and 10° at 24 inches in the soil. The thermometers placed at depths of 4 and 8 inches showed intermediate readings.

It was noted that during August the thermometers at the 16 and 24 inch depths registered about 33° and 31° until the latter part of the month, when the days became shorter and cooler. At this time they fell to 27° and 25°. Hales reasons that "so considerable a heat of the sun at two feet depth, under the earth's surface, must needs have a strong influence, in raising the moisture at that and greater depths; whereby a very great and continual wreak must always be ascending, during the warm summer season, by night as well as day; for the heat at two feet is nearly the same night and day. The impulse of the Sun-beams giving the moisture of the earth a brisk undulating motion, which watery particles, when separated and rarified by heat, do ascend in the form of vapor.

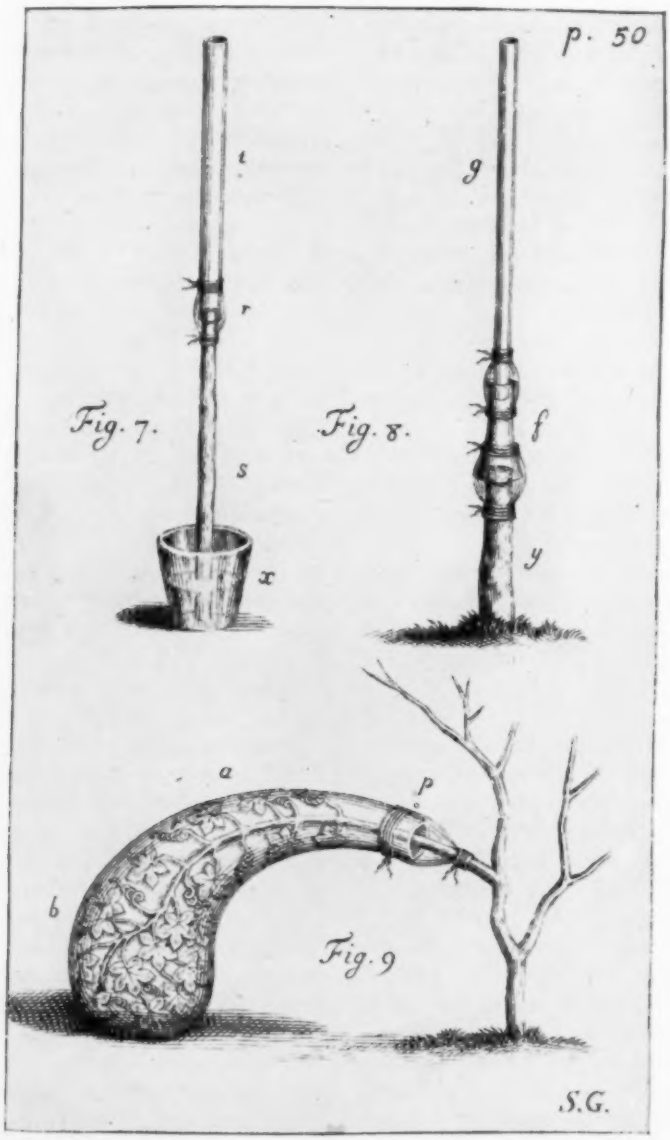

FIGURE 2. FACSIMILE, NATURAL SIZE, OF FIGURES 7, 8, AND 9 IN HALES'S "VEGETABLE STATICKS." FIGURE 9 SHOWS THE GLASS BALLOON METHOD OF MEASURING TRANSPIRATION. FIGURE 7 ILLUSTRATES AN EXPERIMENT IN WHICH HALES FOUND THAT THE WATER IN THE GLASS X WOULD PASS THROUGH THE MOIST TWIG S INTO THE CHAMBER *t*. FIGURE 8 ILLUSTRATES AN EXPERIMENT ON ROOT PRESSURE.

And the vigor of warm and confined vapour (such as is that which is 1, 2, or 3 feet deep in the earth) must be very considerable so as to penetrate the roots with some vigour" (p. 64). "If plants were not in this manner supplied with moisture, it were impossible for them to subsist, under the scorching heats, within the tropicks, where they have no rain for many months together" (p. 65).

Evergreens can endure the winter's cold better than deciduous trees, because their sap is more viscous. Snowdrops, crocus and other early spring plants are similar to the evergreens in this respect. The sap of evergreens in hot countries is not so viscous as the sap of those growing farther north. Plants on the whole are less able to endure low temperatures in the spring than they are in the fall because they contain a greater proportion of water and salt in the spring.

Wind: The tips of winter grain plants that are exposed to the drying winds above the snow cover were observed to fade and turn yellow.

Light: "And may not light also, by freely entering the expanded surfaces of leaves and flowers, contribute much to the ennobling the principles of vegetables" (p. 327).

II. Transpiration

Various ingenious devices were employed to measure transpiration. Cut-shoot potometers, branches enclosed in glass balloons to catch the moisture, as well as entire plants rooted in sealed containers were used (Figures 1 and 2). In the latter case (Figure 1) the unglazed pot in which the plant was growing was covered with thin milled lead, the joints were cemented fast so that no vapor could pass through except air through a small glass tube that projected nine inches above the lead plate. A glass tube, two inches long and one inch in diameter, corked when not in use, for watering projected through the cover. The average day loss of a 3.5-foot sunflower was one pound four ounces, the night loss varied from zero to about three ounces. A medium-sized cabbage plant in a similar container lost on an average about one pound four ounces during the day. *Musa arbor*, the plantain-tree of the West Indies, usually lost more in the six hours before noon than in the six hours after noon. The transpiration of a number of species was compared. The loss per unit area was found to be greater in deciduous plants, like the sunflower, apple and cabbage, than in evergreens like the lemon ("limon"). Twigs of elm, oak, fig, willow, ash and others, placed in potometers, raised a mercury column 1 to 2 inches; those of pear, quince, cherry, peach and plum 3 to 6 inches; but those of evergreens, pumpkins, jessamine and others did not raise the column at all. The areas of the transpiring leaf surfaces and the absorbing root surfaces were compared for several plants. The methods employed can be given best in Hales' own language:

> I cut off all the leaves of this plant, and laid them in several parcels, according to their several sizes, and then measured the surface of a leaf of each parcel, by laying over it a large lattice made with threads, in which the little squares were ¼ of an inch each; by numbering of which I had the surface of the leaves in square inches, which multiplied by the number of leaves in the corresponding parcels, gave me the area of all the leaves; by which means I found the surface of the whole plant, above ground, to be equal to 5,616 square inches, or 39 square feet.
>
> I dug up another Sun flower, nearly of the same size, which had eight main roots, reaching fifteen inches deep and sideways from the stem. It had besides a very thick bush of lateral roots, from the eight main roots, which extended every way in a Hemisphere, about nine inches from the stem and main roots.
>
> In order to get an estimate of the length of all the roots, I took one of the main roots, with its laterals, and measured and weighed them, and then weighed the other seven roots, with their laterals, by which means I found the sum of the length of all the roots to be no less than 1,448 feet.

And supposing the periphery of these roots at a medium, to be 10/76 of an inch, then their surface will be 2286 square inches, or 15.8 square feet; that is, equal to ⅜ of the surface of the plant above ground (p. 5–7).

In a medium-sized cabbage the total leaf area was 2,736 inches, the root area 256 square inches.

In regard to the nature of the absorbing surface of the roots he states that "nature has providently taken care to cover (them) with a very fine thick strainer; that nothing shall be admitted into them but what can readily be carried off by perspiration, vegetables having no other provision for discharging their recrement" (p. 77).

The practical application of the knowledge of the ratio between absorbing and transpiring surfaces was the pruning of many branches from transplanted trees. Hales says that since about half of the roots are cut off from a young tree that has been dug up and only half of the usual "nourishment" can be absorbed it is necessary to cut off many branches. The newly transplanted trees should be well watered, but this should be done carefully so not to give too much, causing the roots to rot and die.

By an experiment using apple twigs Hales showed that the leaves were the most important organs in causing the sap to rise. A twig bearing both leaves and fruit raised a mercury column 4 inches, a twig with leaves and no fruit raised it 3 inches, a twig with fruit but no leaves 1 inch, and a twig with neither leaves nor fruit only 0.25 inch.

The effect of various factors on transpiration was noted. Low humidity, strong light and high temperatures increased it, while high humidity, weak light and low temperatures decreased it. The transpiration of hop-vines was much greater in the shaded, moister garden than in the open. In rainy, moist weather, "without a due mixture of dry weather, too much moisture hovers about the hops, so as to hinder in a good measure the kindly perspiration of the leaves." When the trees are planted too close together he thought that transpiration was decreased to such an extent that poor fruiting resulted or that the shape of the tree became altered. In one experiment he showed that a twig inserted in a potometer raised the mercury column 11.5 inches on sunny days but only 3 inches on cloudy days.

The turning ("nutation") of the stem tip of the sunflower, facing the sun in the east in the morning and in the west at evening, was explained by the greater transpiration of the stem on the sunny side. This caused the stem to shrink on the sunny side, while the opposite side was turgid, and this produced the movement. The same phenomena were observed in the garden bean.

Transpiration occurred in winter as well as in summer. Since this loss did occur in winter, he reasoned, there must also be an ascending sap current at that season also, because the losses must be made good from the supply in roots.

One of the chief values of transpiration to the plant was conceived to be the effect on the concentration of the cell sap. When the transpiration is low "the sap is kept in too thin and crude a state," but when it is fairly high "the sap in the bearing twigs and buds is more digested and brought to better consistence" (p. 134).

III. Growth in Relation to Environmental Factors

Moisture was considered an important factor in growth. "The wetter the season, the longer and larger shoots do vegetables usually make because their soft ductile parts do then continue longer in a moist, tender state; but in a dry season the fibers sooner harden, and stop the further growth of the shoot;

and this may probably be one reason why the two or three last joynts of every shoot are usually shorter than the middle joynts; *viz.*, because they shooting out in the more advanced hot dry summer season, their fibers are soon hardened and dryed, and are withal checked in their growth by the cool autumnal nights" (pp. 333–334). The shorter and poorer condition of the hop-vines growing on the outer parts of gardens as compared with those growing in the center was explained by the greater dryness on the margins. The shade in the center helped to increase the moisture.

Light was considered an indirect factor chiefly. "Beans and many other plants, which stand where they are much shaded, being thereby kept continually moist, do grow to unusual heights, and are drawn up as they call it by the overshadowing Trees, their parts being kept long, soft, and ductile" (p. 334). The lower branches of trees in a thick stand die because since they are greatly shaded they transpire but little. The effect of reduced transpiration was considered to retard the flow of sap and to reduce the amount of nourishment contained in the sap; so evidently the branches died of starvation.

Hales noted that plants and fruits mature earlier in sandy or gravelly soils. This he thought was due to the greater warmth of these soils which was caused by their dryness. Less moisture would be absorbed by the plant, and since transpiration was high the sap would be condensed more quickly and thus hasten ripening.

Root and shoot growth were compared in early spring and summer. He noted that garden peas, beans and winter grains made poor shoot growth in winter and early spring, but the roots grew "well into the warm Earth, so as to be able to afford plenty of nourishment when the season advances, and there is greater demand of it both for nutrition and perspiration" (p. 362). But when peas are planted in June for a September crop they rarely thrive unless the summer is cool and moist, "by reason of the too great perspiration caused by the summer's heat, which drys and hardens their fibres before they are full grown" (p. 363).

IV. Disease in Relation to Environmental Factors

The influence of moisture in promoting disease was noted repeatedly by Hales. "In a rainy moist state of air, without a due mixture of dry weather, too much moisture hovers about the hops, so as to hinder in a good measure the kindly perspiration of the leaves, whereby the stagnating sap corrupts, and breeds moldy fen, which often spoils vast quantities of flourishing hop grounds" (p. 33). Large, thriving vines became heavily infected following a period of ten to fourteen days of rain, because they held the moisture within their shady thickets, while the poor and unpromising hops escaped. Apples, following a rapid growth caused by a rainy spell of ten to fourteen days, rotted "more remarkably than had ever been remembered." An observer is quoted who had noted that mold or fen was more fatal on low and sheltered grounds than on high and open ones, on north slopes than on south slopes, in the middle of fields and gardens than on the edges, and on dry and gentle soils than on moist and stiff ones.

V. Crop Production in Relation to Environmental Factors

Beans and many other plants grow to unusual heights in shaded places, and "this moist shaded state is unsually attended with sterility; very long joynts of vines are also observed to be unfruitful" (p. 334). The colors and odors of flowers were noted to be better in dry soil than in wet. The crop production

of various seasons was compared to various factors, as, temperature, rainfall and pests.

The almost uninterrupted wetness and coldness of the year 1725, very much affected the produce of the Vines the ensuing year; and we have sufficient proof from the observations that the 4 or 5 last years afford us, that the moisture or dryness of the preceding year, has a considerable influence on the productions of the Vine the following year. Thus in the year 1722, there was a dry season, from the beginning of August thro' the following autumn and winter, and the next summer there was good plenty of Grapes. The year 1723 was a remarkably dry year, and in the following year of 1724, there was an unusual plenty of Grapes. The year 1724 was moderately dry, and the following spring the Vines produced a sufficient quantity of branches, but by reason of the wetness and coldness of the year 1725 they proved abortive, and produced hardly any Grapes. This very wet year had an ill effect, not only upon its own productions, but also on those of the following year. For notwithstanding there was a kindly spring and blooming season in the year 1726, yet there were few bunches produced, except here and there in some very dry soils. This, many Gardiners foresaw early, when upon pruning of the Vines, they observed the bearing shoots to be crude and immature; which was the reason why they were not fruitful. The first crop thus failing in many places, the Vines produced a second, which had not time to come to maturity, before the cold weather came on (pp. 74–75).

VI. Root Systems in Relation to Tillage Methods

Tho' we have from these experiments, and from common observation, many proofs of the great expansive forse, with which the fibrous roots of plants shoot, yet the less resistance these tender shoots meet with, the greater progress they will certainly make in equal times. And therefore one considerable use of fallowing and trenching ground, and of mixing therewith several sorts of compost, as Chalk, Lime, Marle, Mold, etc., is not only thereby to replenish it with rich manure, but also to loosen and mellow the soil, not only that the air may the more easily penetrate to the roots, but also that the roots may the more readily make vigorous shoots. And the greater proportion the surface of the roots bears to the surface of the plants above ground, so much the greater quantity of nourishment they will afford, and consequently the plants will be the more vigorous, and better able to weather it out, against unkindly seasons, than those plants whose roots have made much shorter shoots. Herein therefore consists the great care and skill of the Husbandman, to adapt his different sorts of Husbandry to the very different soils, seasons and kinds of grain; that the several sorts of earth, from the very stiff and strong ground, to the loose light earths, may be wrought to the best temper they are capable of, for the kindly shooting and nourishing of the roots. And probably the Husbandman might get many useful hints, to direct him in adapting the several kinds of manure, and different sorts and seasons of culture to his different soils and grains. If in the several stages and growth of his Corn, he would not only make his observations, on what appears above ground, but would also frequently dig up, compare and examine the roots of plants of each sort, especially of those which grow in different soils, and were any how cultivated in a different manner from each other; this would inform them also, whether they sowed their corn too thick or too thin, by comparing the branchings and extent of each root, with the space of ground allotted it to grow in'' (pp. 363–364).

DO BACTERIA HAVE DISEASE?

By Professor J. E. GREAVES

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THE space upon the surface of the earth is limited, as are also the elements which are essential for the growth and normal functioning of plants and animals. Furthermore, there are certain plants and most animals which are so constituted that they must obtain their food in the form of definite compound. This requires that they receive it in a prepared form from the bodies of other plants and animals. These conditions give rise to a constant struggle for existence. It manifests itself among members of the same species; even man struggles with man for a place "in the sun." Species compete with species, the higher preying upon the lower, and so on down the line. Even the little amoeba devours the still smaller bacterium. The bacterium standing at the bottom returns the compliment, on up the line, with a vengeance, the bacteria being the greatest destroyers of all. They stand as the link between the living and the dead, acting as if they were the timekeepers in the race and fight of life. When the higher plants and animals have had their borrowed essential elements for their alloted time, the bacterium intervenes, ends the race and returns the elements to the great earthly reservoir of supply so that they can be used over and over in the never ceasing drama of life.

In this scheme of things it appears as if the bacteria stand apart from other forms of life, inasmuch as they have no smaller organisms to prey upon them. Due to their method of multiplication they never grow old; hence, barring accidents, they may be considered as immortal. It is even argued that they were the first life upon this planet, as some of them can subsist upon the inorganic constituent of the bleak rock watered with the rain, receiving their energy from the traces of nitric acid which it contains. In the course of evolution due to differentiation the higher plants and animals became mortal, thus rendering them liable to natural death and also to disease. While it is true that the single-celled forms of life never grow old and are therefore not subject to natural death, yet there are many facts which have recently been brought to light that indicate that the bacteria do not possess that enviable position of being free from the attack of smaller microorganisms.

Hankin, in 1896, found that the waters of India purify themselves. The Jumna River at Agra contained 100,000 bacteria per cubic centimeter, while three and one half miles below it contained only ninety bacteria. It is a well-known fact that these rivers are highly polluted, yet the disease-causing bacteria quickly disappear from them. This is not due to a poison, for none is to be found in them. It is probably something which is alive, for heat destroys it. While cholera organisms quickly disappeared from the natural waters, yet they actually multiplied in the same water after it had been boiled.

Hoffkin, who was in charge of a laboratory in which vaccine against the plague was produced, noted that some of his cultures of the plague bacteria would grow normally for a time, after which they would disintegrate and all the plague-producing organisms disappear. This was such a common occurrence that

the workers gave to them the name of "suicides." Why did they commit suicide? If it was a suicide what was the weapon used in self-destruction? Today we are learning that they were not suicides, but possibly still smaller organisms were preying upon them.

In 1915 D'Herelle, of the Pasteur Institute, had under observation an adult suffering with a severe case of dysentery. Each day a small amount of the feces was placed in a sterile tube of bouillon. After incubation at 37° for over night, the growth was filtered through a clay filter which removed all the dysentery bacilli. This clear filtrate was added to a second tube to which had been added previously the dysentery bacilli. This was then incubated, and at the end of twenty-four hours the bouillon was cloudy because of the great number of bacteria which had grown within it. This procedure was repeated daily for some time, when one day, upon examining the tubes prepared the day previously, there was found to be no growth. If a drop of this were carried to another tube, it was found that growth was prevented in this tube, even though it had been previously heavily seeded with the dysentery bacteria. After considerable work of this nature, D'Herelle suggested that in the filtrate was a living organism that grew as a parasite upon the bacteria and destroyed them. To this he gave the name of *bacteriophage*, meaning bacteria-eaters. Thus, fulfilling the prophetic words of the poet:

> Great fleas have little fleas upon their backs to bite 'em
> And little fleas have lesser fleas, and so *ad infinitum*
> And the greater fleas themselves, in turn, have greater fleas to go on,
> While these again have greater still, and greater still, and so on.

Having learned that there is a something which preys upon bacteria, many a question comes to the fore: How large are they? Is it possible to see the bacteriophage even with the most powerful microscope? Can they be counted? What do they feed upon? Are there different varieties? If so, do they all attack the bacteria with the same vigor? Can they be used by man to control the disease-producing organisms which attack man? These and many other questions have been asked, and some of them have been answered.

Although the bacteriophage can not be seen even with the aid of the most powerful microscope, yet they have been measured. This is done by passing them through filters the size of the pore of which has been determined. If they pass through one filter of a definite size but not through another just a size smaller, it is known that in size they must be between the two. By this means it has been found that the bacteria are many thousand times larger than the bacteriophage.

Bacteria average about one twenty-five thousandth of an inch in length; therefore, the bacteriophage are less than a thousand this size. It requires five hundred million bacteria to weigh one milligram. It would require many thousand times this number of bacteriophage to weigh this much. It is probable that bacteria are as much larger than the bacteriophage as a fly is larger than the bacteria.

These sizes approximate that of the protein molecule. It seems to leave us in a dilemma. A protein has been looked upon as the basis of life; hence, is it possible to have living organisms smaller than the protein molecule! An organism is looked upon as a cell or an aggregate of cells, and a cell as a mass of protoplasm containing a nucleus. But when we learned of the bacterium we came to define a cell as a mass of protoplasm containing nuclear material. It may be that our conception of some

minute organisms will have to be modified to read: An organism may be a micella which is composed of material more simple than the protein. Moreover, it may be, as suggested recently by Dr. C. B. Lipman, that life originated with very simple compound and not with the complex protein.

The bacteriophage can not only be measured, but they can be counted and their speed of multiplication followed. The procedure is very similar to that used in the counting of bacteria. The number of bacteria in any substance is found by diluting with a measured volume of sterile water. The well-diluted material while in the liquid state is poured into some sterile solid media. On solidifying, the bacteria become fixed on the surface and grow until they become so numerous that they may be seen with the naked eye; just as a clump of trees can be seen in the valley from the mountainside, whereas a single tree may be overlooked. Each group developed from a single organism; hence, if one knows the dilution he can calculate the number in the original sample by counting the number of such colonies.

By seeding measured volumes of the substance to be studied into heavy cultures of bacteria and then pouring onto a solid medium, the bacteriophage can be counted. The bacteria free from the bacteriophage multiply and soon become visible. But where the bacteriophage are present the bacteria are prevented from growing; hence, we have a bare space on the culture media. By counting the number of bare spots on the medium, one can ascertain the number of bacteriophage present. In this way it has been learned that some bacteriophage are found in soil, some in water and others often in the alimentary canal of man and lower animals. Furthermore, it is learned that they multiply more rapidly than do bacteria. They grow only in the body of bacteria, and when from eighteen to twenty-five have formed in the body of the bacterium it explodes; the bacteriophage are liberated and seek other bacteria on which they can prey.

Just as Pasteur found it possible to increase the destructive powers of bacteria by successive passage through the bodies of susceptible animals, likewise D'Herelle found it possible to increase the killing power of the bacteriophage for bacteria by successive cultivation in the body of bacteria. By this means many strains have been produced which quickly devour the typhoid, diphtheria, dysentery and other disease producers. Moreover, these highly active strains are found in the bodies of individuals recovering from these diseases; whereas, when the disease terminates fatally they are usually absent. Hence, they are probably often the determining factors in recovery.

Therefore, we find that bacteria have their diseases as has man. We are prone to wonder if the bacteriophage in turn have still smaller organisms which prey upon them and will science develop strains of the bacteriophage which can be liberated in water and thus free them of harmful bacteria? Will the physician of the future combat the communicable diseases of man by the use of virulent bacteriophage which will prey upon the disease-causing bacteria? Will it be possible to make immunity "catching" as is now the case with disease? The indications are that it will. Time alone will tell.

TACTUAL INTERPRETATION OF SPEECH[1]

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HERE is an experimental situation in which hands are made to do the work of ears; more accurately, a situation in which the touch organs in the palm of a hand or other skin area are performing the function of ears. This function is to receive the vibrations of the atmosphere or of a solid body that have been set up by the spoken word, for example, and to react to those vibrations in such a manner that the subject may learn to know the word or combinations of words and their meaning. This at least is the part of a total function with which I am at present concerned.

It will be apparent that in this adventure we are looking backward over the dim genetic history of our organism as it is—particularly the history of our organs of sense—to near the beginning of organic things, before highly specialized eyes and ears had grown out of the undifferentiated "mother sense of them all," as Stanley Hall described it, the sense of touch. And we are looking forward, also, to a time that may not be far away, when our friends who have lost the use of that enormously specialized organ of touch, the ear (for the ear *is* a refined mechanism for touch) may be enabled to fall back upon the very base of the sense of reality in the infinite and extended array of organs of touch in the skin. For we are here, from an unaccustomed angle, entering the gate of the great archeological field of the psychologist.

This is a suggestion of a program and in some measure a *fait accompli* in "pure" and "applied" psychology that will enlist the whole-hearted cooperation of students of physics and psychology. It is a program that is fit to stir their curiosity and to challenge their genius for experimental control.

When the skin is doing the work of ears we are confronted with a substitute reaction or a substitute reaction system. We have in recent years, especially since the World War, become thoroughly familiar with the phrase and with the fact. Feet are doing the work of hands; they are writing, sewing, handling change and manipulating tools of various sorts. One set of muscles is substituting for another that is suffering paralysis and the effect is a reaction that, to outward appearance, is healthy and adequate. The work of Franz, to name but one in this relation, is full of the meaning that, in the ordinary normal course of events in human life we have only begun to touch the edge of the possibilities of learning to adjust ourselves to our surroundings through the manipulation of our muscles, aided by a new training of sensory capacities. No one has analyzed the unusual processes of substitution that are involved in the learning to which I have alluded. It is more than probable that no one can pick out every factor that plays a rôle therein. No doubt we will all find ourselves in agreement upon the proposition that sensations of contact and of movement, which include a consciousness of position, are prominent criteria from the learner's point of view. But as aids

[1] The author acknowledges the aid that the Bell Telephone Laboratories are giving toward this research. They have provided much of the apparatus that is in use and Dr. Harvey Fletcher is generous with his assistance in relation to instrumental problems.

toward the process of substitution these sensory processes have to be brought from the background to the foreground in attentive states. This is the burden of the subject on whom the experiment is made. In course of time and experience he gets into the way of associating complexes of tactual and kinesthetic sensations that reside in the foot, for example, with the visual perception of something accomplished, whereas formerly he was in the way of making a similar association with tactual and kinesthetic sensations localized in the hand. In the last analysis the process probably comes down to the discrimination of sensory processes that have been in darkness heretofore.

Familiarity has bred indifference to many palpable evidences of the capacity of organs of touch to distinguish very small differences. Before I go on to my main problem let me rehearse a very few of these evidences.

We are familiar with the substitution of touch for vision in the case of the blind. We have begun almost to take this phenomenon for granted. The blind read by touch as rapidly as we do with our eyes; they associate tactile impressions with the meanings that others of us connect with visual impressions of the printed page; and there is no reason for assuming that any other sensory mechanism than that of touch is implicated in the performance. But not only do they employ the tactile organ in their finger tips to fit themselves into their world. After a brief period of trial and error they find their way with surprisingly little confusion amongst the buildings and trees of the campus—and without painful accident. For the touch organs in the skin of the face have taken up the burden of serving as a medium whereby the subject learns, without direct contact, of the nearness of an obstructing tree, post or pillar. Changes in the direction or pressure of air currents against the skin, alterations so slight that others of us do not observe them, become the sensory signal of such obstructions and the subject reacts accordingly. Whether this is due to an absolute increase of sensitivity or to trained attention need not concern us here. The fact is that in these circumstances behavior is altered by extraordinarily slight occasions. The accomplishments to which I have alluded afford a great amazement to the neighbors of our sightless folk who are not accustomed to thinking of the unfathomed capacity of the skin, after training, to substitute for eyes. I do not forget that in this relation the auditory apparatus comes to reinforce the tactile forces.

It has become a truism amongst students of evolutionary processes in the animal kingdom that the nervous system is an ingrowth from the skin and that highly specialized organs of sense have grown out of the primitive, undifferentiated organs of touch.

And this leads to my main purpose in this paper which is to state the hypothesis that in cases in which a specialized sense organ, notably the organ of hearing, has ceased to functionate, the organs of touch in the skin may be made to serve as a substitute. And having stated the hypothesis I shall set out direct supporting evidence for it from my own observations, and indirect evidence from the work of others.

In the first place numerous more or less casual observations serve to strengthen the hypothesis. Times without number I have noticed a group of deaf subjects whose audiometric measurement is as low as from 0 to 30 assume an attitude of attention in response to a light stamp upon the floor; a stamp that occasions a disturbance so slight that I can not believe a person of normal sensory equipment would observe it through touch alone. This is the method by which teachers of the deaf habitually attract the attention of their pupils. They feel the rhythm of the piano and

the orchestra through the floor and learn to dance to it. While they apply their fingers lightly to the frame of the piano they catch by touch the rhythmic sequence of musical tones. This is a commonplace phenomenon in schools for the deaf. But more than this, they are in many places actually distinguishing the pitch of a musical tone and reacting to it. How great a degree of accuracy the deaf can attain in this relation it is impossible for me to say. But the circumstance as it is suggests an interesting possibility to which I shall make allusion later. As a matter of course observations of this sort have not always been made under experimental conditions, and some discount upon them may be necessary. But after all our discountings, and after we have made all our allowances for the enthusiasms and prejudices of casual observers, a residue of inescapable fact undoubtedly remains: a residue of fact that at least adds respectability to the tentative conclusion that our organs of touch are devices for adjustment of so delicate quality that, if properly trained, they could catch the musical phrases of the human voice and differentiate them with a clearness sufficient to enable the subject to associate meanings therewith. To this end we will assume, as a matter of course, that it will be necessary to adopt some mechanical contrivance to amplify the vast succession of stimulations and to bring them to bear upon a pattern of tactual organs with best effect.

Experimentally controlled observations upon the capacity of organs of touch to differentiate the vibrations that correspond to human speech are available.

Two years ago one of my own students, a hearing subject whose auditory organs were completely isolated from stimulation, distinguished thirty-four words uncombined in sentence form. When selected words from the list were combined to form sentences, he grasped their meaning; and numbers of combinations were so employed. No more complicated mechanical aid was brought into requisition in this instance than a metallic speaking tube one end of which was closely covered by the learner's palm while close against a funnel at the opposite end was the mouth of the speaker. It is beyond one's power to conceive of the infinite patterns of stimulating pushes of air from the speaker's mouth through the tube against the subject's palm that made all these discriminations possible. But in time the discriminations were made and with a high degree of accuracy. Not only so, but thereby something new was built into the subject's personality; how permanently I can not say, but after the summer vacation following—a period of no practice—when he returned to us he had dropped but thirteen points on his learning curve from 92 to 79. This is a forgetting rate for tactile stimuli, under our conditions, of but a trifle more than 14 per cent. The whole observation speaks eloquently enough of a forgotten angle of the energies of men. May it not be that cycles of time in which the great upward evolutionary push of life, building form after form of more and more complicated organic devices for adjustment, have covered up primitive functions at the foundations of the structure; functions that have become vestigial and that can be led to resume their usefulness when there is need? Here may be a discovery, or a rediscovery, of a substitute for a highly specialized organ of sense.

And so the stage has been set by these observations for a more refined method and for more intensive application. The speaking tube has been discarded. In its place we have a telephonic sort of device. What would be the ear-piece in a telephone system or in an acousticon is held in the hand of the learner, so that he *feels* the words of the speaker at the other end of the system quite as you and

I hear what our neighbor is saying to us from beyond the central exchange. We thus obtain a sharper tactual impression and probably a wider range of tactual patterns than we obtained in the speaking-tube situation. The theory is that no two sentences and no two words feel precisely alike. There may be the minutest difference in many instances; so slight that to the untutored they are non-existent, but yet distinct enough to emerge into the consciousness of the highly trained. And I have personally become aware of this emergence in the case of the words: "a," "e," "i," "o" and "u" so that I could identify them ninety-one times in a hundred. They do not feel alike. One is rough and another smooth; they are long and short; one has two camel back humps upon it. They taper from indistinctness to distinctness and the reverse. There must be an infinitude of shades of difference when the touch characters that correspond to these spoken words are combined with vocalized consonants and with surds. Obviously it would be a work of Hercules, but by no means an impossibility, to make a tactile survey of such combinations as these to correspond to an auditory survey such as has been made by aid of a high quality telephone. It has been begun and it will ultimately be finished. Even with relatively crude devices on the order of the telephone my deaf-mute subjects have learned with a high degree of accuracy to identify any one of twenty sentences of six monosyllabic words each, a large number of words uncombined in sentence form and certain vowel values pronounced in isolation. They pick up a simple story by touch and show encouraging indications of a growing capacity to combine the feels of words into hitherto strange sentences, even though several unpracticed words may be thrown into the gaps. That is to say, they are commencing to do by touch what hearing people are doing by hearing all the day. For how many of the separate words uttered from across your dinner table do you really hear? Many of them you fail to hear as words at all. But you fill in the gaps; you get the sense of it all and you enjoy companionship with your dinner guests. Not the least encouraging feature in connection with this experiment in interpretation of speech by touch is the fact that the progress I have referred to has been made in but one daily practice period of only twenty-five minutes, five days weekly from the middle of October, 1924. School vacations and examination periods and days of absence for sickness, etc., have come out of these weeks. When all deductions have been made each subject is found to have practiced only about fifty-five hours to the end of the academic year 1924–1925. And furthermore it must be borne in mind that the deaf-mute subjects can hardly be expected to be burning with zeal for the experimental work. They can communicate with each other so easily by manual signs and they are by no means of the sort of well-trained laboratory students. On the other hand they approximate much more closely to the average freshman in college.

The fundamental facts in relation to the hypothesis I stated a while back have been demonstrated directly in experimental conditions. It is possible to understand speech by the agency of touch alone. How wide may be the scope of capacity for understanding in this manner? Experiment and experiment alone can afford a satisfactory answer.

Certain indirect evidence is at hand in support of the hypothesis that lies at the basis of this discussion. This evidence serves the double purpose of throwing light upon the usefulness of our hypothesis and of pointing out the direction that further researches must take if they are to furnish an answer to my question as to the *range* of our capacity to understand speech by touch.

In the first place how sensitive is the skin to tactual impressions? It is a mat-

ter of common observation that sensitivity varies with the area that is stimulated. On the forehead and temples a pressure of two thousandths of a gram will occasion a sensation of touch; two thousandths will serve upon the finger tips likewise. A much heavier pressure is required for this purpose upon the back of the neck. On the palm of the hand four thousandths of a gram has been determined to be the minimal stimulus; and the same figure, approximately, describes the sensitivity of the skin of the abdomen. But such determinations as these are made for but a single contact and upon subjects who have not been specially trained over a prolonged period. It is impossible to say with any approach to exactness what the figure should be, assuming a very rapid succession of minimal stimuli upon a given narrowly circumscribed area. Certainly our casual observation suggests that in such circumstances a stimulation by considerably less than the figures quoted above should occasion a sensation of touch. For there is such a thing as a summation of stimuli—or better perhaps in this case—an increasing excitability of a sense organ. Witness the experience of a squirrel hunter. After several months of no practice he distinguishes inexpertly at best the body of a squirrel from the bark of a tree. But after a day or so in the woods he makes the distinction unerringly. It is as if the sense organ had become keyed up by use. A drop of water falling through a short distance upon the face occasions a very slight and a pleasant sensory disturbance. Let it be repeated periodically and with very short intervals for a few minutes and the same intensity of stimulus awakens a succession of sensory experiences that are not only distinct but may be even painful.

But because we are interested in the possibility of transmitting the ordinary vocal vibrations characteristic of speech to the skin and in making them impinge thereon in such manner as to enable the subject to understand what is being spoken, we are concerned with more than the absolute sensitivity of the skin. We want to know its *relative sensitivity;* relative, that is, to the sensitivity of the ear. Assuming that we have the fractional gram weight that is essential to arouse a sensation of touch is it comparable with the shock of air impulse measured in fractional grams that is required to awaken an auditory sensation? If there is no considerable coincidence of stimulus ranges in these two sensory areas, and no possibility of developing such a coincidence, further pursuit of our experimental inquiry is already doomed to futility. But there is no occasion for entertaining a fear upon this point.

We are indebted to Dr. Fletcher, of the American Telephone and Telegraph laboratories, for searching investigations relating to the sensitivity of the ear. Speaking only of the hearing of pure tones these investigations show that variations of air pressure upon the auditory mechanism ranging from one one thousandth to one one hundredth of a gram will arouse sensations of tones whose frequencies range from approximately 200 to 16,000 per second. This is assuming a suitable energy of vibration. When the pressure upon the auditory organ is increased to one tenth of a gram we have a situation that is adequate to occasion sensations of tones whose frequencies range from 64 to approximately 16,400 per second. Recall now the fact that single contacts involving pressures of two and four thousandths of a gram, respectively, upon the forehead and palm are adequate to arouse a sensation of touch. If two thousandths of a gram weight were descriptive of the very slightest stimulus that in the most favorable circumstances could occasion a sensation of touch we should be able to obtain through the skin an impression that corresponds to tones whose frequencies range from 512 to more than 8,000 per second, provided that the sensory mechanism would permit of discrete sensations, without

fusion, in the higher range. But I am confident that a normally sensitive subject, after considerable practice, may distinguish pressures of very much less degree than is indicated by the figures I have quoted. At the same time I am not able at the present moment to submit experimental data in proof.

Assuming that what has been presented to this point is a conservative statement of the facts, it is evident that the relative sensitivity of the skin and the ear presents no insuperable obstacle to the ultimate understanding of speech by touch; and this may be said even if it were not possible to lower the threshold for touch beyond the limen that I have mentioned for the forehead, finger tips and palm.

In this connection it must be remembered, too, that suitable devices enable us to amplify vocal vibrations and thus to compensate for the insensitivity of the skin relative to that of the ear.

Another problem is before us: assume, if you please, that the threshold for touch is capable of reduction to whatever level may be desired. If, however, variations in pressure against the skin should fuse when they succeed one another at the rate of 128 to 256 times per second and above so that a fork, for example, vibrating at such a rate against the skin should seem to be not in motion but quite at rest we should at once probably find ourselves lacking an essential criterion for distinguishing speech. But fusion does not occur at any such low level. When it does come to pass in a highly practiced subject is impossible to say at this moment with anything approaching exactness. Dr. Herrick states that it does not occur below 1,552 complete vibrations a second and von Wittlich, more conservatively, places it at 1,000. If this is a fact it is of extraordinary importance for this investigation, for the reason that the frequencies employed in ordinary conversation are probably for the most part below 1,000. The point of fusion is capable of experimental determination and it must be pressed to a conclusion. Suffice it to say that instructors of the deaf regard it as no accomplishment worthy of more than a remark when their pupils, after three or four exercises, with fingers resting lightly upon a piano frame, distinguish the C of 256 vibrations from the C of 512 vibrations, and from a rate midway between the two. But the niceness of discrimination between the two extremes is, of course, a problem in itself, distinct from that of the limits. This, too, is open to experimental examination, and it must be pushed to an issue.

In conclusion, we are entitled at the present stage to a very high degree of confidence that a mechanism may be developed and a method whereby deafened pupils in their seats at school may be made to understand by touch what the instructor is saying to them. There are other possibilities; touch may be made an aid in teaching and in learning to read the lips; and it can now be asserted as a fact that deafened folk who have lost or are losing control of their voices may reestablish control by aid of a suitable medium between the vocal organs of a speaker and the skin of the subject. When the vocal vibrations from a speaker's mouth are translated into sensations of touch upon the skin of the deaf-mute he has a set of cues whereby he is able the better to control rhythm, phrasing, pitch, enunciation, accent and emphasis. When these things shall have been accomplished there may next be found a way whereby our deafened friends may know what we are saying to them in social intercourse because they can feel our words through the medium of the genetically oldest sense organs that are common to the animal kingdom.

This is an expression of confidence in the all but untouched and certainly unfathomed possibilities in human learning, and also in the zeal of men of science to pool their energies and their acumen regardless of artificial boundaries between physics and psychology.

THE INTELLIGENCE OF DELINQUENTS IN THE LIGHT OF RECENT RESEARCH

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LOMBROSO'S theory of a criminal class distinguished by definite physical stigmata is no longer held by scientists. It has been supplanted, however, by an equally simple and not dissimilar theory —the theory that a large percentage of delinquency is due to inborn mental weakness, measurable by psychological tests. The tendency among advanced thinkers to-day is to make responsibility a matter chiefly of intelligence. It is held that a large percentage of delinquents are too defective mentally to distinguish right from wrong. These should therefore not be punished, but segregated permanently in institutions where they will be given humane professional care. Thus they will be prevented from harming society either through committing further crime or through leaving offspring who because of inherited mental defect would be potential delinquents. It is held that the menace to society from these defective delinquents is all the greater owing to the circumstance that they are *high-grade feeble-minded* (morons) and therefore not superficially distinguishable from the ordinary population.

It is men of science who have furnished these generalizations, on the basis of which sociologists and zoologists, physicians and judges, journalists and men on the street defend their conviction that mental deficiency is a very important, if not the chief cause of delinquency. Dr. H. H. Goddard, one of the best-known psychologists in the United States, has been a pioneer in the development of mental testing and has fathered numerous experimental investigations of delinquency. He says in a book published in 1915: "The best estimate and the result of the most careful studies indicate that somewhere in the neighborhood of 50 per cent. of all criminals are feeble-minded. . . . Careful studies have shown beyond the peradventure of a doubt that at least two thirds of these mental defectives have inherited their defect."[1] Professor L. M. Terman, in 1923 president of the American Psychological Association, said in a book published in 1916, "There is no investigator who denies the fearful rôle played by mental deficiency in the production of vice, crime and delinquency."[2]

In view of such pronouncements as these by authorities in the field, it is seen to be inevitable that juvenile court judges and others who deal with delinquents should have their present attitude —should be always ready, upon the slightest indication, to infer mental defectiveness in their charges. Nor is it surprising that educated people in general should so readily associate delinquency with innate defect, should even be alarmed about the possible fate of a society which harbors innocent-looking individuals whose hereditary defects may cause them at any time to commit anti-social outrages. Truly, if half the delinquency in society is the result of inborn mental defect, it is time we looked to the quality of our human stock!

[1] Goddard, H. H., "The Criminal Imbecile," Chapter VI.

[2] Terman, L. M., "The Measurement of Intelligence," Chapter I.

It is my primary purpose in this paper to show that this whole modern attitude is grounded upon an error—one of the most regrettable, I believe, in the history of the new biological science of psychology. The social workers are sincere, the judges fair-minded, the average educated person intelligent. But they are all misinformed. Psychologists as well as many outside the field have been guilty of over-hasty generalization, of an over-zealous attempt to apply prematurely the findings of a science yet in its infancy, findings that should have been given to the public, if at all, as purely tentative. They realize their mistake now—the natural progress of scientific work has resulted already in a profound modification of the early generalizations, and the scepticism of the many psychologists who were critical from the first has been justified.

In order to understand the present status of the experimental investigation of the intelligence of delinquents, it is essential to know why and how this modification in psychological thought about the problem has come about. I shall therefore first review very briefly the original methods used in developing and standardizing the tests and shall then describe briefly the main developments of the mental testing movement, in their relation to our problem.

The chief tests used have been the Binet-Simon tests, invented in 1905 by Binet for the purpose of selecting backward children in the public schools of Paris. These tests had the advantage over the miscellaneous tests previously used in laboratories of being organized as a system, with standards of performance set for each age of childhood. There were a large number of simple tests—questions to answer, puzzles, stories to interpret, numbers to repeat and the like. The method of fixing the age standards was as follows. Quite a number of children of a particular age, say eight years, were given the tests, beginning with the easier ones. It was then determined what was the average number of tests these children passed successfully. Assuming this particular group to be typical of eight-year-old children in general, a certain range of achievement on either side of this average was set as being the normal range for eight-year-olds. Hereafter any eight-year-old child whose test record fell within this range was said to be normal. If his score in the tests was the same as the average score for the standard group, he was said to have a mental age of just eight. For every test he passed, a certain fraction of a year's credit was added to the mental age already earned. If a child failed to pass enough tests to reach the previously determined standard range, he was said to be under age, or below normal mentally. Thus a given eight-year-old child might be able to reach only the six-year average, and no higher. He would then be said to have a mental age of six or to be two years retarded mentally. If a child succeeded in passing tests above the standard set for his age, he was said to be over age, or mentally above normal. For instance, a particular child of eight might succeed in reaching the nine-year average. He would then be said to have a mental age of nine.

In the original edition of the tests as published in 1908, *there were no tests for adults*—that is, none above the thirteen-year level. It would follow that a person who passed all the thirteen-year tests could not be fairly compared with the standard group, for there would be no means of telling how much higher he might be able to go. There were found to be other disadvantages and defects, arising chiefly from the fact that the number of children of each age originally tested in determining the normal standard of performance was too small, and the children apparently not representative of children in general, but of a particular selected group or class.

Binet tried to remedy some of these defects in another revision published in 1911. This revision included tests for fifteen-year-olds, and another group for adults. In commenting on it, Binet showed that he realized clearly its tentative character, and especially its inadequacy for adults. In the same year he died. Before the close of that year Dr. Goddard, who had already been responsible for the introduction into this country of translations of the two early editions, published a new revision of his own, which we will refer to as the Goddard revision. It was better adapted for American use than Binet's 1911 edition, chiefly because of the use of more distinctively American terms, but in essentials was the same.

As soon as they were published these three early revisions found widespread use in America. It is not hard to account for the enthusiasm with which they were received. At last, it seemed, we had an objective method of *measuring* human intelligence. Moreover, the method was simple and could be applied directly toward the solution of pressing social problems. Articles on the tests flooded both technical and popular magazines. Psychologists everywhere turned from sterile problems of the laboratories to work feverishly with the new tests. Doctors, teachers and social workers also used them, for they were so simple that it seemed they could be given by any one. And so before they were carefully worked out or standardized they were applied wholesale, not only to school children, but to special groups of adults, as foreigners, Negroes and inmates of reformatories and prisons.

The first results of the application of the tests to delinquent and criminal groups were "astounding." They indicated percentages of feeble-mindedness in such groups, varying roughly from thirty to ninety. Instead of trying to interpret these figures with the caution which the hasty and unscientific character of the work demanded, sociologists and psychologists alike accepted them at face value as throwing a flood of light on the problem of delinquency.

As a matter of fact the whole of this earlier work is to be looked upon with suspicion. The conclusions are utterly unreliable. Why? In answering this question we may class all the early editions together, for they suffered from the same general defects.

Why? In the first place the tests were insufficiently standardized. Since everything depends upon the relation of the mental age earned to the standard for a particular age, it is clear that a number of *unselected* individuals of each age should be tested in fixing this standard. But only a very few were actually used, and these were not, in general, typical groups representing the whole population. This is especially true of the adults. Also, there were not nearly enough tests provided for adults. As a result of this incomplete standardization it soon became evident to the trained psychologists who used the tests that for one thing the tests for the upper years in the scale—eleven, twelve, thirteen, fifteen and adult—were *much too hard*. This point has great importance for our problem. According to the standards used by Goddard and most of the workers in this country, adults with a mental age of eleven were considered to belong in the class of high grade feeble-minded. Many investigators put all with a mental age of twelve or less in or below the same class. Now the great majority of the delinquents tested were either adults or "children" in the teens. Hence it is clear that it is just the age standards found to be too high which would be applied to delinquents, who would thereby be placed at a great disadvantage. Since we have no means of determining exactly what these delinquents might have been able to do had the tests

been carefully standardized, it is clear that the only scientific attitude is to consider the results worthless as far as quantitative statement is concerned. This point of over-difficult standards for the upper ages is only one of many defects which made the results unreliable, but it is the outstanding one for our problem.

A second reason why most of the early results are unreliable is the fact that methods of giving, scoring and interpreting were far from uniform. This lack of uniformity is partly due to the fact that three different scales were used, partly to the absence of a single standardized procedure, and partly to mere carelessness.

Even if the tests themselves had been perfect measures of intelligence, and the procedure carefully standardized, we would still find it necessary to cast out of court much of the early work. This is because in a great many cases the investigations were made by inexperienced or poorly trained examiners, who had no conception of scientific method—by teachers, social workers, students, doctors—by any one interested. The interest usually betokened a bias, and the methods and interpretations could not but be influenced by that bias. Yet strangely enough there was little discrimination among investigators, even on the part of psychologists.

Some psychologists, however, questioned from the first, and as time went on the volume of criticism increased. The first step was in the direction of establishing accurate standards by testing many *normal* people. Attention was concentrated on children first—not for years were the tests given systematically to any large number of normal adults. Yet people went on talking confidently about the low intelligence of adult delinquents, as if it were possible to state how much less intelligently these handled the tests than normal adults, before any normal adults had been tested.

Scattered testing of adults, however, soon began to arouse suspicions as to the accuracy of the adult standard. For example, Dr. J. E. W. Wallin gave the Goddard 1911 revision to some respected and successful Iowa farmers. All were rated according to the tests as middle or high grade feebleminded.[3]

The results of the early testing of delinquents, then, are utterly unreliable. Yet we must remember that it is on precisely these results that our present attitude toward the intelligence of delinquents is largely based. Scientific research is often centuries ahead of popular opinion, but we sometimes forget that it is also many years ahead of ordinary cultured or semi-popular opinion. There are even scientists who have not yet had a vision of the tentative science of the future, the science which will consider the publication as truth of a hasty generalization to be a more heinous sin than perjury or murder.

Finally, in 1916, Professor L. M. Terman published a complete new revision of the Binet tests, with procedure carefully standardized and age norms much more reliable. He had added more adult tests and changed the method of scoring in such a way that adults were not so heavily penalized. Gradually the new revision has come into general use. When it is applied to delinquents it is found that the percentage of defectiveness as measured on this scale is markedly less than had been found when the old standards were used. This is because, the upper tests being less difficult than before, a person tested can make a higher mental age than he could have made on the older scales. Now, instead of percentages of feeble-mindedness ranging from 40 to 90, investigators report such percentages in reformatories and prisons as 30, 15 and 25. Yet here, as prevailingly before, all adults having a mental age of eleven or under are considered probably feeble-minded.

[3] Wallin, J. E. W., "Problems of Subnormality," Chapter 2.

With the publication of the newer results based on the Terman scale many psychologists began to revise their conceptions of the relation of defectiveness to delinquency. But they still considered it an important factor, though a less important one than they had supposed. More conclusive evidence, however, was soon to force them still more radically to revise their opinions.

With the publication of the complete results of the testing in the United States Army, in 1921, the status of our problem was again altered. Terman, taking the average performance of thirty business men and thirty-two high-school students as typical of the adult population of the United States as a whole, had fixed upon the mental age of sixteen as the average adult standard. But when his own scale was applied to 653 unselected adults in the army, it was found that they had an average mental age of only about thirteen. Ninety-three thousand men, constituting a sample of the entire white draft, were given tests similar to the Terman-Binet tests. Their scores were expressed in terms of mental age, and it was found in their case also that the average mental age was about thirteen. Plainly this means that even the Terman revision still heavily penalized the average adult. The whole white draft, or even the 653 men, of course are a much fairer sample of the general population of the United States than Terman's 62 business men and high-school students of California. Possibly the intelligence of the draft is slightly below that of the general population, for the draft did not include many officers previously sent to special training camps. This is offset, however, by the fact that men obviously feeble-minded were not included in the draft either, and so it is generally recognized that if the average test performance is any lower than would have been that of the total population, it is so only to a very slight extent.

The army figures, interpreted according to the Terman standards, would mean that the *average* citizen of the United States (if we consider the white draft as a representative group) is just above the upper line of "borderline deficiency, often classified as feeble-mindedness" (Terman).[4] They would mean that approximately 20 per cent. of the general population of the country is definitely feeble-minded, or of still lower intelligence, and that about 25 per cent. classify as borderline deficients. These figures afford no basis whatever for continuing to assume a relatively larger proportion of mental defectives among delinquents than in the population as a whole. Few workers with the Stanford scale have found among delinquents higher percentages than these.

Interpreted according to early standards, still widely prevailing, let us remember, from 30 to 47 per cent. of the white draft, and hence about that percentage of the entire population of the country, would be called feeble-minded!

When we consider what would happen even to the more recently gathered Terman data on defectiveness among delinquents were the army standards applied, we can see that the percentage of feeble-mindedness estimated to exist would have to be greatly reduced, and can fairly conjecture that it might even be negligible. So far there has been practically no direct application of the new standards, but results obtained by the older method of scoring are now being interpreted in the light of the new findings, with the result that percentages of feeble-mindedness (as measured by the tests) found even in institutions are very much lower than prevalent publications would indicate. As an example, the average mental age of 447 delinquent women confined in certain institutions in

[4] Terman, L. M., "Measurement of Intelligence," Chapter VI.

New York State was found by Fernald, Hayes and Dawley (1920) to be 11.8, which is four and a half years less than the average mental age assumed by Terman. But it is only one and a half years less than the average mental age of the army group. According to Terman's standards, the delinquent women would appear to be strikingly inferior in intelligence. Fernald, Hayes and Dawley, however, conclude conservatively: "With regard to intelligence, all indications are that the group of delinquent women is somewhat inferior to the general population, though *the difference is slight and the overlapping large,*" (italics mine).[5]

Investigations recently made with the use of the Army Alpha tests (the same general type as the Binet, but devised for group use) would indicate no higher percentage of mental deficiency among the inmates of penal institutions than in the army. The Army Report (1921) shows that the 3,300 inmates of Leavenworth Prison made a slightly higher average score in the Alpha tests than the 94,000 men of the white draft.[6] Murchison (1920) gave the Alpha tests to 3,328 white criminals, and found them to have exactly the average intelligence score made by the white draft.[7] Recently (1924) more extensive research by Murchison has abundantly corroborated this work.[8] Other investigators report similar results.[9]

Thus when we apply to ordinary non-delinquent adults the same standards that we have been using for the study of delinquents, we find among them also nearly or quite the same amount of defectiveness as in delinquent groups. Now it is patently absurd to call from 20 to 40 per cent. of our population feeble-minded. We have clearly no right to say that a mental age of eleven or so indicates probable feeble-mindedness, when a large percentage of our adult population whose mental age would be no higher are known to be fully capable of keeping their place in society. They do not meet the ordinary definition of a feeble-minded person, as being one who is "incapable, from mental defect existing from birth or from an early age, of . . . managing himself and his affairs with ordinary prudence."[10] It has been assumed that the "high-grade moron," found in such large numbers in our institutions, is *incapable* of knowing the quality of a criminal act, that he is too stupid to form moral judgments. If the delinquent moron is to be relieved of responsibility on this score, then certainly the non-delinquent moron should similarly be absolved from allegiance to moral standards, and perhaps 47 per cent. of our population should be treated as children.

It is true not only that the "morons" among us show little tendency to delinquency, but it is also true that of those who in recent years have been confined in such large numbers in institutions, a great many, after discharge, have proved themselves capable of leading ordinarily happy and efficient lives in society. Follow-up observations on former inmates of the institution for the feeble-minded at Waverley, Massachusetts, furnish a case in point.

Such considerations as the above make it glaringly evident that our standards for interpreting the testing of delinquents are wrong. We psychologists will

[5] Fernald, Hayes, Dawley, "A Study of Women Delinquents in New York State," 1920.

[6] Memoirs National Academy of Sciences, 1921, Vol. XV, p. 800.

[7] Murchison, Carl, "Criminals and college students," *School and Society*, Vol. XII, July 3, 1920.

[8] Murchison, C., "American White Criminal Intelligence," *Jour. Criminal Law and Criminology*, 1924, Vol. 15, pp. 239–317, 434–494.

[9] See Pintner, R., "Intelligence Testing," 1923, pp. 288–293; also Gault, R. H., "Criminology," *Psychological Bulletin*, Oct., 1925 (summary with bibliography).

[10] Quoted from formulation of the British Royal Commission on the Feeble-minded (1904).

have to make many more careful investigations in the light of the newer standards before we can offer even an approximately reliable numerical estimate of the percentage of feeble-mindedness or mental deficiency as measured by tests among delinquents in institutions. Already, however, we have scientific proof that the earlier and still prevalent estimates were greatly exaggerated, and there are clear indications that the percentage of feeble-mindedness in the whole delinquent group may be only slightly greater, possibly no greater, than the percentage of feeble-mindedness in the population as a whole.

At the beginning of the testing movement tests poorly given and illy interpreted gave unfortunate impetus and direction to a strong popular conviction. But we must remember that more of the same kind of tests, well given and carefully interpreted, have now given us sure grounds for questioning that conviction. It is not the method but its use which was at fault. Without tests we should be again lost in a hopeless maze of speculation. It is through their aid alone that we can hope to make progress toward the attainment of positive and objective knowledge about the intelligence of delinquents.

EARTHQUAKES[1]

By Commander N. H. HECK

U. S. COAST AND GEODETIC SURVEY

WHENEVER man begins, in any field, to think that he has at last succeeded in the constant struggle with nature, he receives a reminder that when nature sees fit to put forth her whole force his best efforts are helpless. He builds a *Titanic*, and an iceberg sends it to the bottom of the sea; a town is built near a volcano, and all living beings are silenced in a single breath; a tornado sweeps across a city and the best built structure falls before it. There is, however, nothing which brings the feeling of helplessness to large numbers of men more than a severe earthquake. Something happens in the interior of the earth, waves move along the surface and the surface of the earth itself may be torn apart; that surface on the stability of which men base all their plans. Their buildings may fall or be seriously damaged or given over to the unrestrained activity of another force of nature—that is, fire.

In the United States we are interested in earthquakes at the present time because a number have occurred during the past year and a large area of the country has felt earthquake shocks. Fortunately many of these were not severe and the others were not of the most severe type. What is an earthquake? There are a number of answers to this question, but for the moment we will consider that as a result of a shock in the interior of the earth waves roll along the surface. These waves have been actually seen at times. They are somewhat like those at sea, but near the earthquake center they are usually more confused than sea waves. A solid surface like the earth, in many cases, is too rigid to take the form of the waves, and in such a case the surface may be broken apart, leaving chasms, though frequently the waves pass along without fracturing the surface. The reason that the earthquake waves do damage to buildings is largely because they are not built to stand the peculiar strain. As a wave passes along, the bottom is tilted in one direction, while the top is a little delayed in responding to the tilt. The bottom is then tilted in the other direction, and there is again delay on the part of the top; the result is that not only is the building severely racked at all its joints, but a vibration is set up so that unless the building is strong enough to act as a whole it may be entirely shaken down. An example of the worst type of building for an earthquake region is found quite commonly in Japan. Heavy tiles are placed on a light structure; when the earthquake comes the structure begins vibrating and in itself would stand the earthquake very well, but the roof breaks apart, the tiles start to fall and kill any one caught within the building. This was a cause of serious loss of life in the 1923 earthquake in Tokyo.

The earthquake waves in many cases are not regular like the waves which roll in on the beach at the seashore. This has been proved by a study of the direction in which statues fell in one of the great earthquakes in Japan. Near the center of the earthquake statues fell in every conceivable direction. In other

[1] Broadcast from Station WRC, Washington, October 29, 1925, under the auspices of the Smithsonian Institution and the direction of Mr. Austin H. Clark.

places there was a general direction to their fall, but many did not fall in the same direction as the others. These confused waves may put very varied strains on buildings, and only those of the best material, properly fastened together, will stand.

The passing earthquake waves have, in some cases, left some very interesting traces. In 1906, during the California earthquake, a railroad train was turned over on its side, while the rails and the bed of the railroad showed little trace of disturbance. In this case the crest of the wave was parallel to the railroad track. The train was tilted over, just as a ship rolls as the crest of a wave passes. We have an example, however, in the Charleston earthquake of 1886 and in several in Japan that when a wave passes along diagonally to the railroad track it twists the rails into S-shaped curves going off into the distance. In certain formations the earth itself may remain in the form of the passing waves until the rains finally level it to its former condition.

At times chasms open in the earth. In the recent earthquakes in Montana, near the town of Three Forks, cracks several feet wide and a number of feet deep opened in a roadway and remained. The story is told of a case in California where a crack opened and a cow dropped in. The crack then wholly closed and the only evidence left was the cow's tail sticking up out of the ground. Whether this incident is true or not, it is true that the cracks often close after the earthquake is over. It is quite clear that when such cracks occur below a building, damage will result, no matter how well it is constructed, but these occurrences are comparatively rare.

Perhaps even more effect on the earth's surface results indirectly from earthquakes by the setting off of landslides. In the case of the earthquake of 1906 in California, in San Francisco where the earthquake was severe, more damage was done by the starting of fires and preventing their extinction than by direct action. Insofar as the surface of the earth was concerned, the effect was much greater north of San Francisco, in a relatively unsettled region, where numerous landslides occurred. During the recent Montana earthquake, landslides occurred which caused some damage and inconvenience in railroad operations. Some years ago in western China, a great earthquake occurred which caused landslides on an enormous scale. The earth happened to be of a peculiar formation and was apparently water-soaked at the time. As a result, the landslides were so vast that a section of a road was carried nearly half a mile. It was stated that a great many caves were buried in these landslides and that these caves were largely occupied by priests of the Mohammedan religion. So many of these priests were buried that the non-Moslem Chinese said that this was an indication of the falsity of the religion. Furthermore, a serious rebellion was suddenly brought to an end, for the leading general and all his staff were caught in the collapse of one of the caves.

The damage to buildings and changes of the earth's surface are nearly always confined to a certain region which may be large or small, according to the earthquake, but the earthquake waves thus set in motion do not stop at the edge of this region but usually travel for long distances, in some cases around the earth, and in rare cases twice around the earth. When the central region has been left these tremors, as they are usually called, can be detected only by instruments. Such tremors occur in Washington quite frequently, as is evidenced by the records of the seismographs at Georgetown University and at the magnetic observatory of the Coast and Geodetic Survey at Cheltenham, Maryland.

eighteen miles south of Washington. Even if we can not feel these tremors, the recording of them is of great importance in the study of earthquakes. With good records we are able to find out where an earthquake occurs, even if it is out in a desert region with no inhabitants or if it is under the sea. The details of the method, while not very difficult to grasp, are perhaps not appropriate to a radio talk, so I will give you an illustration in order that it may not seem entirely mysterious. Suppose that you stood on the edge of a pond and that on the other side some one threw in a pebble when you were not looking. You would see the approaching ripples and could tell from what direction they came and so could face the place where the pebble struck the water. Now suppose that another person did the same thing at a point on the edge of the pond some distance away. You would both be facing the point from different directions so that it would be possible for you to direct a man in a boat to drive a pole into the bottom at the point toward which you were both looking. The pole would undoubtedly be quite near the pebble resting on the bottom, even though neither of you had seen it strike the water.

In the case of earthquakes there is a method which gives the direction, but it is easier to find the distance from the earthquake to the place where the seismograph is established, and by knowing the distance from several stations we can readily compute the place where the earthquake occurred. You have frequently seen reports from Georgetown and other universities in which it was stated that a certain earthquake occurred a certain number of miles from Washington in a given general direction, but usually this is all that a single station can do. In some of the more important earthquakes, in accordance with arrangements made by Science Service, telegraphic information, in code, is received from a number of stations and then the United States Coast and Geodetic Survey works out the position and within a day after the occurrence states definitely where the earthquake occurred. Recent examples have been an earthquake off the coast of Kamchatka and another in Honduras.

There are many theories as to the cause of earthquakes, but none has been absolutely proved. It is known, however, that there are actual breaks in the earth's crust at certain places, and that such breaks have usually resulted from strains in the earth's crust. In many cases the strains have continued and they are relieved usually only by slipping along the break. When the slip occurs suddenly, an earthquake is almost sure to result, and then the waves are sent out in a way similar to that when a pebble strikes the surface of a pond. The forces involved in an earthquake are very great, but in many cases an earthquake may be set off by a small force. This force does not, in any way, cause the earthquake, but it does determine the instant when it occurs.

As an example of this we know that at times large buildings have failed by the falling in of the roof. It is not impossible that such a roof could be so delicately balanced that it would be ready to fall for several days and then a very slight force, such as the vibration of a passing truck, could fix the exact time for the fall. In the same way, the slip which produces the earthquake can be ready to occur and the exact instant will be fixed by such a cause as a change in barometric pressure due to a passing weather disturbance, a heavy shower, melting snow or an exceptionally high tide on the coast. None of these in themselves could cause an earthquake, but any of them may determine exactly when an earthquake, otherwise ready, will occur.

You probably would like me to tell you whether or not there is going to be a severe earthquake in the United States in the near future. No one can answer this question. We have had severe earthquakes across the Maine border in Canada and in South Carolina, in the east; in the upper Mississippi Valley in the middle west; in the Mountain States and the adjoining parts of Mexico; and on the Pacific Coast. The probability of a severe earthquake in the east or middle west is small, but not too small to ignore. In the past each period of earthquake activity has developed great interest which has quickly disappeared after a short period. I hope that this time a program will be fully established so that not only will we have more information when the next earthquake occurs, but we will begin to understand the laws governing earthquakes.

There are many indications that we are now beginning to go at this problem in the right way. The government, through the Coast and Geodetic Survey, is operating seismographs, collecting information about earthquakes and publishing the results in useful form, and will do more of this as time goes on. The Weather Bureau helps in collecting earthquake reports for the United States when the earthquakes are felt. The Geological Survey examines regions where earthquakes have occurred. Many of the universities and colleges are operating seismographs, and in this matter the Jesuit institutions are especially active. You are probably aware of what is being done by Georgetown University here and Fordham University in New York. Of this group, St. Louis University is about to start investigations in the Mississippi Valley in the region where a great earthquake occurred many years ago. The Carnegie Institution of Washington is, with the cooperation of the government and various institutions, directing a detailed investigation into local earthquakes in California. National organizations of architects, civil engineers and builders are studying codes and methods of insuring safer buildings and other structures in earthquake regions. The fire insurance companies are especially interested in the prevention of loss by earthquake, and there are many signs that activity in earthquake investigation is now starting upon a sound basis in the United States, and it will go on until we have learned more about how to meet earthquake danger in this country and the rest of the world than we have heretofore.

PERPETUAL MOTION IN THE TWENTIETH CENTURY[1]

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

IT is an eloquent comment on the extent to which the twentieth century has modified our traditional physical concepts that it should be possible for a scientific man (otherwise in good standing) to submit an essay on perpetual motion to the SCIENTIFIC MONTHLY and that it should be accepted and published. Such being the case it behooves all of us who profess and call ourselves physicists to examine with care the foundations of our traditional belief in this matter.

Prior to the introduction of the concept of energy and the formulation of the principle of its conservation it was indeed generally believed that perpetual motion was impossible; but this belief rested not upon any general principle but on the fact that a careful examination of every proposed device of this character disclosed some flaw. It is probably true that this examination of individual cases played its part in bringing about the recognition of the general principle that the creation of energy was impossible. Once well established, the principle of the conservation of energy became a closed door against which inventors of perpetual motion machines knocked in vain, unable to obtain a hearing.

A little later came the statement of another general principle—the second law of thermodynamics. This asserted, in brief, that heat could not run up-hill of itself; that if a hot body was placed in contact with a colder one the tendency would be to equalize their temperatures, not to increase the difference.

For this down-hill tendency no specific reason was at first assigned. As originally formulated by Clausius, the second law was purely empirical, an appeal to experience, and as such, as Clausius himself says, it did not find a ready acceptance in the minds of other persons.[2] The analogy of the down-hill flow of water was imperfect, for there the governing influence of gravitation was evident, while in the case of the flow of heat there was no recognizable controlling force. That heat usually *did* flow down-hill was an admitted fact; but that it always *must* was, in the minds of many, an open question. Schuster says[3] that about 1875 both Balfour, Stewart and Wien had such doubts as to the generality of the second law that they were experimenting (independently) in the hope of finding a case where it would break down.

Perhaps they were influenced in this by Maxwell, who about that time showed that the operation of the second law could be suspended by the interposition of intelligence.[4] His famous concept of "sorting demons" is well worth study to-day. He showed how, given an intelligence able to handle and sort single

[1] Published by permission of the director of the National Bureau of Standards, of the U. S. Department of Commerce.

[2] Clausius, "Die Mechanische Warmetheorie," 3rd edition, 1887, p. 82: "Dieser von mir als Grundsatz hingestellte Satz hat viele Anfechtungen erfahren."

[3] Schuster, "Progress of Physics from 1875 to 1908," p. 22.

[4] Maxwell, "Theory of Heat," 1875 edition; Appendix, "On the Limitations of the Second Law of Thermodynamics."

molecules (and we have made a long step toward realizing this since Maxwell's day), it is possible, without expending any work or violating the principle of the conservation of energy, to warm one half of a mass of gas by cooling the other half—in other words, to make heat run up-hill.

The work of Boltzmann and of Planck during succeeding years did much to place the second law on a more satisfactory basis—one of probability. Boltzmann showed that the spontaneous equalizing of the temperatures of two bodies was in effect merely the passage of the molecules of these bodies from a less probable to a more probable arrangement. The hypothetical flow of heat up-hill was thus seen to be not impossible, but merely improbable.

An example will illustrate this point. The law of gaseous diffusion is closely similar to the law of flow of heat, diffusion always tending toward a state of uniformity. Differences in density, like differences in temperature, if left to themselves, tend to disappear rather than to increase. It would be just as surprising to see a gas, originally of uniform density, crowd itself spontaneously into half the volume, leaving the other half a vacuum, as it would be to see heat run up-hill.

Suppose a volume of gas so small that it contains but two molecules, one in each half of the volume. These molecules are continually in motion, rebounding from the containing walls and passing back and forth irregularly from one half of the volume to the other. We may have four possible different arrangements:

A	B
B	A
AB	
	AB

Of these four possibilities, two represent a vacuum in one half the space. The probability of such an occurrence is therefore 1/2, that is, it may be expected to occur half the time.

As the number of molecules increases the probability of a vacuum arising in this way decreases rapidly. For a total of n molecules the probability that half the volume will be empty is $\frac{1}{2}^{n-1}$, which, for the enormous number of molecules ordinarily dealt with, is to all intents and purposes zero. For the much more probable case that the pressure in the two halves of one cubic centimeter of a gas should differ by one per cent. the probability is still so small that such a condition may be expected to arise spontaneously only about once in $10^{10^{18}}$ years!

One point needs emphasis in this connection. If an occurrence is so rare that it may be expected to happen on the average once in an eon, it must still be borne in mind that it does not necessarily follow that we will have to wait that long to see it happen. There is nothing to prevent it happening at the end of the next five minutes; the probability of that is exactly the same as the probability that it will happen at the end of an eon. It might even occur twice in the next minute; but if it did it is possible that time itself might not be long enough for it to happen again.

A similar line of reasoning leads us to an analogous conclusion with respect to the possibility of the spontaneous appearance of temperature differences. The temperature of a gas is determined by the velocity of its molecules. In a gas at what we consider constant temperature the velocities of the individual molecules are far from being the same, but are distributed about a mean which remains constant. Consider a volume of gas so small that it contains only four molecules, two equally fast-moving ones, F_1, F_2, and two equally slow ones, S_1, S_2. The various possibilities of arrangement (assuming that there is no change in density) are six in number:

F_1 S_1	F_2 S_2
F_2 S_1	F_1 S_2
F_1 S_2	F_2 S_1
F_2 S_2	F_1 S_1
S_2 S_1	F_1 F_2
F_1 F_2	S_1 S_2

Of these six possibilities the first four represent cases of equal temperature in the two halves of the gas, for our temperature measuring instruments can give us only a mean value. The last two, however, represent differences of temperature, the probability of which (for four molecules) is consequently 1/3.

With an increase in the number of molecules the probability of any large difference of temperature resulting in this way becomes rapidly less; yet we must recognize that in any volume of gas that we can handle the temperature of any and every small portion is continually and imperceptibly fluctuating up and down and that on the whole the gas is no more uniform in temperature than the surface of the ocean is absolutely level.

That sensible differences of temperature may arise in this way is, of course, highly improbable, but not impossible. We must, however, recognize the fact that heat not only *can* run up-hill, but that it is continually doing so on a very small scale; and that perhaps once in a blue moon we might actually observe it.

We can now understand that hard saying attributed to Planck: that if a kettle of water be placed on the fire there is a chance, though an exceedingly small one, that the water will freeze!

Once it was recognized that up-hill changes in temperature and density were continually occurring on a very small scale, the question was raised whether it was not possible by some device to accumulate these changes until a sensible effect could be produced and useful work obtained. Such a device may be called a perpetual motion machine of the second kind, as it obtains work not by a creation of energy, but in spite of the second law of thermodynamics.

Several such devices have in fact been proposed by Lippmann, of Paris,[5] and Svedberg, of Upsala.[6] In 1912 Smoluchowski[7] published an extended discussion of the theory of the subject and as a result laid down the general principle that we can hardly hope to accumulate these departures from the second law on a molecular scale by any device built up of molecules; for every such device is itself subject to molecular variations which, in the long run, will probably cancel out the variations that we hope to pick up by its aid. Smoluchowski's argument, however, is not final, but only discouraging.

Be this as it may, it is sufficiently novel and surprising to recognize that the second law can be said to be valid only in a statistical sense, in the long run; yet twentieth century thought is already pushing still farther and hinting at the possibility (on a molecular scale also) of perpetual motion of the first kind—the actual creation of energy; for Professor Debye in a recent address[8] has warned us that in order to reconcile the phenomena of interference with the quantum concept it may be necessary to assume that the conservation of energy itself is true only statistically; that energy may be created and annihilated, in minute fluctuations, its average remaining constant in the long run. What will be the outcome of this, no one can as yet say; but it is possible, in these iconoclastic days, that this doctrine may sooner than we think become unimpeachably orthodox.

[5] Lippmann, Rapp. du Cong. Int. de Phys., Paris, 1900; Vol. 1, p. 546.

[6] Svedberg, *Zeit. phys. Chem.*, Vol. 59, 1907, p. 451.

[7] Smoluchowski, *Phys. Zeit.*, Vol. 13, 1912, p. 1069.

[8] Address at the Bureau of Standards, March 11, 1925.

THE PROBLEM OF ANEMIA

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MANY years devoted to the study of disease have indicated that certain age groups more so than others are susceptible to particular ailments. Thus in the first decade we find measles, scarlet fever and diphtheria most common. The second and third decades are characterized by the prevalence of tuberculosis; the fourth and fifth by tumors and heart defects and the sixth by arterial disease. Among the multitude of diseases which afflict human beings are many associated with blood changes designated as anemia, which is usually observed as a variable degree of pallor. The appearance of the skin and mucous membranes, however, as an index of anemia is frequently deceptive, for pale individuals may have a normal hemoglobin content and the state of the blood can only be accurately determined by mensuration with special apparatus, such as hemoglobinometers and blood-cell counting pipettes.

Anemia is properly regarded as a symptom and not a disease. The condition is most frequently seen in young and middle-aged persons and appears to be more common now than in former years. It may arise from a variety of sources, and, while physicians speak of a primary and secondary anemia, in reality there is no primary anemia or blood disease of this type, since the blood changes are always secondary to an exciting cause. The anemias associated with loss of blood or its elements within the circulation may for diagnostic purposes be divided into four main groups: (1) pernicious anemia, (2) secondary anemia, (3) aplastic anemia and (4) leukemia. This does not represent a scientific medical classification but suffices for the purpose of the present discussion. Frequently in the above groups one merges into the other so that sharp differentiation is not always possible.

Perhaps the most remarkable tissue in the body is the blood and it may rightly be considered a tissue since it consists of cellular elements enclosed in a stroma, which in this instance is the blood plasma. The blood penetrating to every part of the body acts as the great medium of exchange, carrying to the tissues oxygen and the necessary food elements and removing to the excretory organs the waste and harmful products. It will thus be appreciated that the blood, although possessing marvelous powers of adjustment, is exposed to injury from a great many sources. The air we breathe when vitiated by a harmful gas leaves its impress on the blood; injurious substances may be absorbed through the skin and even the food and fluid we take may, if unsuited to the individual, be productive of undesirable haemic changes. If the efficiency of the blood is impaired, then all the organs of the body suffer in proportion precisely as the crippling of a transportation system has a demoralizing effect on the activities of an entire community. Small wonder then that anemia is so common when one considers the many avenues by which the blood may be attacked.

Most existing illness is due to infec-

tions, and infections, either acute or chronic, are invariably associated with some degree of anemia. These infections may be very evident in their onset and progress and again may be so insidious as to remain unrecognized until the patient is quite ill. The natural tendency of most disease is toward self-cure, but many diseases do not so terminate and repeated trauma to the blood may result in mortal injury to that tissue and its formative organs. The blood, after a fashion, also acts as a solvent for poisonous substances which may accumulate in certain organs, causing great damage there, while the blood itself shows but little change. The circulation also acts mechanically in transferring bacteria from one point to another.

The blood is a highly complex fluid, but in the condition of anemia our attention is directed to but one element—the red blood corpuscle or erythrocyte. This minute cell, thirty-two hundredths of an inch in diameter, is a biconcave or cup-shaped disc consisting of a very thin membrane enclosing a protein material, namely, globulin, in which is found the iron-containing pigment or hemoglobin. The cell has a faint straw color, but in bulk or by reflected light appears red. The erythrocyte is exceedingly pliable and is without a nucleus, thus being unlike all other body cells. In its developmental stages the red blood cell possesses a nucleus, but this is lost when the cells enter the circulating blood after birth and the appearance of nucleated red cells in the post-natal period is distinctly pathologic. The blood elements are readily examined microscopically in the fresh state, but when spread on glass in the form of a thin film and stained with certain combinations of aniline dyes the cells appear more clearly defined and any intracellular structure or parasite becomes visible. The cells are inconceivably numerous, and as well as can be determined there are approximately 5,000,000 to each cubic millimeter of blood. Their large numbers thus permit of an enormous absorbing or oxygenating area.

The structure of the red blood cell is not clearly understood. There appears to be an outer limiting membrane and a framework or stroma holding in its mesh the hemoglobin. The function of the hemoglobin is to act as an agency for the transfer of oxygen and carbon dioxide. Within the cell are also salts, cholesterin and lecithin, which appear to exert an important function in retaining the hemoglobin within the cell membrane. The outer limiting membrane is a homogeneous structure, colloidal in character, and permits free passage of osmotic currents. The red cells maintain their shapes in the serum or in physiologic salt (0.85 per cent.) solution, but when placed in concentrated salt solution the cells shrink or if the salt content be decreased the cells swell and finally rupture, allowing the hemoglobin to escape. Recognition of this fact is of extreme importance in routine hospital work, where solutions are so often introduced directly into veins.

The fundamental facts that bacteria are responsible for infection and that the symptoms induced are due to toxins generated by the bacteria are now universally recognized. Regardless of what part of the body is infected the toxins are absorbed by the neighboring blood and lymph vessels and distributed to all the tissues and organs. Some bacterial poisons have a selective affinity for certain tissues or organs. Thus the toxins of tetanus and polioencephalitis attack the nervous system; of syphilis, the vascular system; mumps, the parotid glands; smallpox, the skin and mucous membranes; streptococci, the blood and bone-marrow. Similarly, we find chemical poisons exerting a selective action. Lead affects the blood and nervous system, phosphorus and copper the liver

and bichloride of mercury the kidneys. Disorders of metabolism, malnutrition, scurvy and rickets are all associated with varying degrees of anemia, and the blood changes of anemia are a pronounced feature of all malignant tumors.

It has been previously stated that most illness is due to bacterial infections, and the majority of these are of a chronic nature. Virulence of the infecting agent and resistance of the body are extremely variable factors. After the first onslaught by bacteria with the body the victor, the microbes may yet remain indefinitely within the body leading a partial parasitic existence. Nevertheless, in this state they are constantly generating poisons of a low toxic effect, but the continuous presence of poisonous substances in the blood and organs must necessarily have a harmful action. Since the blood is the carrier of these toxins we find early changes present in the form of anemia, that is, a decrease in the number of red blood cells or of hemoglobin or both. Examination by means of special instruments shows that this alteration is brought about in two ways, either by decreased production or increased destruction of the blood elements. Certain toxins destroy the red cells, while in the blood stream others depress the bone-marrow function where the red cells are formed, thus decreasing their numbers in the circulating current. Regardless of the mechanism involved, the end result is the same and the patients present identical symptoms with reference to anemia.

By way of illustration we may consider malaria. In this infection the malarial parasite lives and develops within the red blood cell and in the process of development totally disrupts the cell. Millions of these elements are thus destroyed every second or third day faster than regeneration can take place and the resulting effect is anemia. In hookworm infestation the repeated bites of many worms in the intestine causes daily loss of considerable blood, so that after some weeks or months a distinct anemia results. The process here is similar to the steady or intermittent loss of blood from an ulcer of the stomach and experimentally an animal such as the rabbit when bled daily or several times weekly from an ear vein soon develops a profound anemia from which it may not recover even though the bleeding is not continued. In certain diseases of cattle, such as Texas fever, a parasite enters and destroys the red cells in such large numbers that the hemoglobin thus set free appears in the urine in sufficient quantity as to color it quite darkly.

A more subtle form of blood destruction also takes place. Infections due to the streptococcus group are common. Biologic study of certain members of the group shows that among other products the organisms produce a substance called hemolysin, which when brought into contact with red blood cells causes their dissolution. Similar action obtains in the circulating blood during infection by these same organisms and in the case of the more virulent strains a rapidly developing anemia ensues. A more chronic destructive action is brought about by other members of the group with resulting prolonged anemia. Many other bacteria also generate similar hemolysins of varying degree of potency and the same process is seen in exaggerated form following the injection of snake venom. The exact nature of the process is obscure but probably is dependent upon certain physicochemical activity bringing about increased intracellular pressure. Hemolysins not normally resident in a given animal's blood may be caused to appear by injecting into that animal the red blood cells of an alien species so that when the blood serum of the injected animal is brought into contact with the red blood cells of the second

animal hemolysis is produced. This phenomenon is taken advantage of in certain diagnostic tests, as in the Wassermann reaction. Many of these toxic substances also injure the endothelium, the delicate lining of blood vessels and so permit considerable loss of blood by exudation.

Pernicious anemia is the *bête noir* of physicians. Insidious in onset it is usually well established when discovered by a blood test. This examination discloses the characteristic features of the disease, namely, marked variation in size and shape of the red blood cells. Many of these are quite small, others large and pale, still others are oval, pear-shaped, tailed or appear fragmented. They are so altered that it is very apparent that the cells function but poorly. The reduction in the number of red cells and the corresponding decrease of corpuscle oxygenating surface tend to make the patient weak and short of breath upon the slightest exertion. In the fully developed disease the patients have a curious pallor, a lemon-yellow tint to the skin which is fairly characteristic of this form of anemia.

The actual cause of pernicious anemia is unknown, except in the case of infestation by the fish tapeworm (Dibothriocephalus latus). In the presence of these parasites the blood changes are typically those of pernicious anemia and death results if the patient is not relieved of the worms. The reason for the particular harmfulness of this parasite appears to be due to the fact that it secretes saponin, a substance which is hemolytic for red blood cells. But not all the infected cases develop anemia. Poisoning by toluylenediamine causes excessive hemolysis, resulting in anemia of the pernicious type and there are other chemical agents which act in a similar manner. In many instances localized bacterial infection, particularly about the mouth, appears to be responsible for the anemia. Severe cases of pyorrhea and abscesses of root sockets in which streptococci are abundant have been observed in association with severe anemia bordering on the pernicious type and that the relationship is a causal one is indicated by the disappearance of the anemia upon removal of the infection. At many points in the body collections of bacteria may exist constantly giving off substances having a hemolytic action. Many cases of secondary anemia have their origin in such hidden foci of infection.

A more unusual form of blood disease which is acute in onset and associated with infection is aplastic anemia. Here we find in the circulating blood stream a steady decrease of red and white blood cells. The loss finally becomes so great as to be incompatible with life. Examination after death discloses a marked impoverishment of the bone marrow which explains the anemia. The injury is so profound that although the exciting cause be discovered and removed the marrow appears unable to regain its function of producing blood elements. Fortunately this type of anemia is rare.

Leukaemia, a disease which appears in two forms, myeloid and lymphatic, is also associated with profound blood changes and in fact can only be accurately diagnosticated by examination of the blood. In this disease the essential features are marked increases in the various forms of white blood cells, but there is also a decrease in the red cells and percentage of hemoglobin. So augmented are the leucocytes that the condition has been likened to a tumor of the blood, for the cells appear to increase in the peripheral circulation as well as in the bone-marrow, spleen and liver. The red cells may finally become fewer than the white cells or leucocytes, and when this stage is reached the patient is usually "in extremis." Leukaemia is also associated with hyper-

plasia or overgrowth of the lymph nodes, spleen and bone-marrow, and in the latter situation it is the white cell elements and not the red that are increased.

Here, then, are several diseases of the blood with the same underlying factors —a steady loss of hemoglobin due to the escape of blood, destruction of red cells or inhibition of the blood-forming tissues. In some instances the causative factors are easily demonstrated, in others they are obscure. The mechanism of the morphologic changes in pernicious anemia is poorly understood, but it is not unlikely that they are due to alteration in surface tension. By varying the salt concentration of plasma or even by subjecting normal blood to the influence of heat one can produce distorted red cells similar to those found in pernicious anemia. The extreme delicacy and plasticity of the enclosing membrane of the red corpuscles facilitates rapid variations in size and osmotic relationships and certain abnormal factors might readily tend to "fix" the cells in their irregular forms. Such altered cells are more fragile than normal.

A few metallic poisons exert a direct deleterious action on red cells. In plumbism the erythrocytes appear pale and are reduced in numbers. Many take on peculiar staining characteristics. It is thought by some workers that the absorbed lead salts tend to make the red cells so fragile that they can not withstand the traumatism in the blood stream and consequently undergo fragmentation, the broken parts being retained in the internal organs such as the spleen and liver, where they are demonstrable on microscopic examination in the form of complete or incomplete red cells or altered blood pigment.

Thus we find that in a great variety of diseased conditions anemia is present and may be the only early evidence of something abnormal in the body. The examination of the blood indicates the form of anemia and leads to search for possible causes which in most instances are detectable. When an inflammatory process, as in a tonsil, sinus, tooth or bone, is discovered complete relief of the secondary anemia follows proper treatment of the infection. But the problem is much more serious in the other forms of anemia, where careful and repeated search often reveals no cause. Coincident with the blood changes in pernicious anemia there is in most cases a total absence of hydrochloric acid in the gastric juice, but supplying this deficiency to the patient does not cure the anemia. The real cause is still unknown and may not be the same in all instances. Secondary anemia is the most common form of blood disease, and more important than determining its presence is discovery of the cause, which is feasible in most instances and eradicable.

MODIFICATIONS DUE TO HUMAN AGENCIES IN THE MARINE LIFE OF THE PACIFIC COAST

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MODIFICATIONS in the marine life of the Pacific that have been brought about by human agencies may be treated under five headings: (1) Modifications due to commercial exploitation; (2) disturbing of the balance of nature by the unequal drain on certain species by such exploitation; (3) modifications due to the changing of conditions in the sea and along the shore; (4) modifications due to changing conditions that affect anadromous species; (5) the introduction of new species.

COMMERCIAL EXPLOITATION

As in many other instances, man's interference with the life of the sea has produced, in the main, destructive modifications. He destroys directly for his own advantage or to suit his whim, and he destroys indirectly by carrying out plans for his own profit without paying any attention to the disturbances that may result.

If toll were taken from all species alike there might be little disturbance in the natural balance, but that is not the way it works out. The species that have suffered from direct destruction are those that can be or have been put to some commercial use. They may be used as food for human beings or for domestic animals, their pelts may be used as fur or leather, oil may be extracted from their tissues or they may be used, entirely or in part, as fertilizer. Even among the species that might be used for one or more of these purposes fancy has had its fling, and in consequence the effect of man's destructive power has been borne by comparatively few species that have thereby suffered serious depletion if not complete extermination.

Apart from the matter of fancy, two things must determine what species will be sought—the total value of the commercial products obtained from one individual of the species and the cost of obtaining, preparing and distributing these commercial products. Other things being equal, the large organism will be taken in preference to the small, the gregarious in preference to the solitary, and the inshore and readily accessible in preference to the deep sea and less accessible. Many of the mammals are of such large size and may be of such high commercial value that these factors outweigh all the others combined. In general, the large species and the gregarious species have suffered to the greatest extent.

Possibly the best example of rapid extermination by exploitation on the Pacific coast of North America was that of the *Rhytina* or seacow, the largest of the Sirenia. Reported for the first time by Steller, the surgeon-naturalist, who was with Bering when his ship was wrecked on the Commander islands in 1741, this large, helpless, herbivorous animal was found to be excellent for food. It was soon hunted by the people of Siberia as well as by whalers and sealers until within fifteen years practically

all of them were killed. In 1768 the last one was reported. There were thus but twenty-seven years from discovery to extermination.

The history of the sea otter is almost as tragic if not so brief. A hundred and fifty years ago the sea otters were so plentiful along the coast, and particularly along that part west of Vancouver Island, that it was considered worth while, even in those days of slow navigation, to fit out vessels in England and Spain to sail around the Horn to trade in sea otter skins. Always valuable on account of the quality of the fur, they were slaughtered in great numbers, as they lived near enough the shore to be readily accessible. The numbers rapidly decreased, but the value of the hides increased and the hunting became more and more intense, with the inevitable result. To-day no other fur can approach the value of that of the sea otter, but there is probably not a single animal alive on the coast of British Columbia and there are very few on any part of the coast, although since 1911 they have been wholly protected.

The story is repeated in the case of the elephant seal, although since it lived in a much more restricted area, the case is not so spectacular. Only a very small remnant, let us hope that it is a saving remnant, of the species exists to-day.

The plot was laid for another similar story with the fur seal as the sufferer. The introduction and the preliminary chapters were written and staged. The quality of the fur serves as the incentive to slaughter. For a time a lack of knowledge of the periodic migration and the distant and inhospitable location of the rookeries did much to prevent rapid destruction, but soon the definiteness of the breeding season and the segregation in such large numbers at that season offset the deterrents in other directions and the annual kill became greater and greater. The climax was reached when the migration route became well established and pelagic sealing brought about an even greater drain on the fur-seal herds, partly because such a large number of pregnant females were included in the slaughter. The stage was all set for the last act, the act of extermination, but the performance was not carried out. The people of four countries, through their governments, interfered. The exploitation is now so controlled that the numbers are rapidly increasing instead of decreasing, although a considerable annual revenue is derived from them. While such sensible handling of the situation prevails, "to be continued" will take the place of "finis."

The whale, although it is so large and of such great commercial value, has been in less danger of rapid depletion, as the different species are not so gregarious as the sea cow, fur seal, etc., because they live more in the open sea and because, particularly in the case of the whalebone whales, their very existence depends on their active life in search for food. In the earlier days of small whaleboats and hand-thrown harpoons, the whale had a fair chance of holding its own, but when these were replaced by power boats, harpoon guns and explosive bombs, this chance disappeared. The only saving grace lies in the fact that modern methods are expensive and hence although some species have suffered great depletion, almost to extermination, there is not the same danger, as in other species, since, when the numbers in any area become too small, it is not commercially profitable to hunt them.

The walrus has long been hunted, and even though the methods still used are rather primitive, large numbers are accounted for. In many places where formerly they came ashore in large numbers, the wholesale slaughter has driven them away entirely. When they are hunted on the ice, there is a large economic waste, for many that are killed are not retrieved and in the case of those that are retrieved it may be possible that

only the tusks can be taken ashore. The flesh, or most of it, valuable as food, is left to decay.

The sea lion is in a somewhat different category. It has not been hunted very extensively on account of its commercial value but rather because of the damage it does to some of the established fishery industries. It does considerable damage in some localities, but the life history is not well enough known to be sure that it may not have as much to its credit as to its debit. As is commonly the case with animals in general, those who are affected by the damage done at certain times of the year have their eyes closed to any good that may be done at other times. In certain localities there has been great depletion of the species on that account, but I am not sure that the total number along the whole coast has been materially diminished since more extensive killing began.

Of the birds, the game birds, such as ducks and geese and their allies, have been killed off for food. In many areas these are much scarcer than formerly, but that this decrease in numbers is even largely due to the fact that they have been shot in sheltered waters along the coast is open to doubt. They are all migrants and they suffer even greater loss of life in other parts of their migratory course. Probably the draining of marshes has had more to do with the decrease than any other single factor.

There is not the same reason for the disappearance of the once picturesque feature of the landscape in many parts of the coast, the bald eagle. On account of the bad reputation he has or has had —I do not feel at all sure that it is well deserved—a bounty has been placed on its head, and now one seldom sees a single bird on the trees where, such a short time ago, the white heads showed up everywhere.

On the other hand, the various species of gulls, protected and even fed by man, are thriving mightily. It is true that their eggs have been used to some extent in some localities, but this can not have a great or even an appreciable effect on the whole gull fauna.

It may be going too far afield, except to mention it as an example, to refer to the wholesale slaughter of albatrosses and other large sea birds on Laysan Island, some years ago, and the much more recent destruction of birds and birds' nests on that island through the introduction of rabbits.

Of the fishes, the halibut has possibly suffered the most when its whole range is considered. Of large size, slow at reaching maturity as compared with most other fishes and to some extent at least gregarious, it is not standing the strain of the heavy fishing. Bank after bank has been more or less completely fished out, forcing the fishermen farther and farther afield. For the halibut, though, as for the fur seal, apparently the dawn of a better day has arrived. An international halibut commission has arranged for an investigation upon which may be based regulations looking to the conservation and restoration of this great fishery. The problem is much more complex than the fur seal problem, but there is no reason to doubt that it can be solved.

Another large fish, the sturgeon, although it has not come into the commercial prominence the halibut has, is in greater danger of extermination, with at present, no indication of any relief. Possibly it should not be called a marine species, although it reaches tidal waters.

Whenever North Pacific fisheries are considered the salmon question must come up. The individual salmon are not so large or so valuable as the halibut, but the fact that they occur in such great numbers and that they all go up into fresh water to spawn makes them so readily accessible that they provide the most important industry on the coast. The king salmon and the coho suffer persecution continuously, as they will take

bait at all times of the year throughout their whole life. The sockeye, the humpback and the chum never do so and they are thus free from attack while they remain in the open sea. Unfortunately for them, though, they all school extensively as they enter the rivers to go up stream to spawn, thus becoming easy victims to the net. No Pacific fishery has been more subject to regulation than the salmon fishery, but much of the regulation has been of no avail, if it has not been actually harmful, because there was too little information upon which to base it. Such information is gradually accumulating, and with the spirit of international cooperation in conservation that exists to a greater extent than ever before (in fact, until recently it was almost non-existent), there is reason to believe that the salmon may long continue to provide material for the greatest fishery on the coast.

We might go on to speak of herring and pilchard, tuna, albacore, smelt, oolachan, sable fish, gray cod, ling cod, rock cod, flounder, sole, brill, etc., all molested by mankind to a greater or less degree. Some of them have been fished at certain centers much beyond that which the supply could stand, but there is not definite information enough about the life history of any of these to say that this is true for the whole coast.

Of the invertebrates, the exploitation has been confined almost entirely in the North Pacific American waters to the mollusca and crustacea, and these, shore and shallow water forms. Because of this the fishing has been intense in certain centers, so intense as to bring about great depletion, in some cases almost complete extermination, but as to the extent to which this local depletion affects the whole coastal distribution it is not possible to tell from the information available. This must vary much with the species. The oyster, the abalone, various species of clam, including the razor clam, the cockle and the scallop, among the molluscs, to which might be added the squid and the octopus for oriental use, and the crab, the spiny lobster and the shrimps, among the crustacea, are of great enough importance to merit consideration.

Of plants, little can be said under this heading. During the war, certain kelps, mainly *Macrocystis*, were used extensively for the production of potash and then and since, to a slight extent, for such by-products as algin, iodine, etc., but the amount used could have had little lasting effect on the general supply.

Disturbing the Natural Balance by Unequal Drain on Species

As an antithesis to the exploitation of commercially valuable species, there has been a lack of destruction of animals that prey on these. The result of this is twofold. Since the numbers of certain species are so much reduced, while the animals that prey on them are not so reduced, those that remain are hunted more persistently, so that the situation, serious enough, is further aggravated. Even with more zealous hunting by these predatory forms, enough food may not be obtained from the species formerly attacked and attention may or must be turned to other species, thus bringing about unwonted destruction among these. The upsetting of the natural balance may have far-reaching results.

Many parasites are restricted in their distribution to one species as their host. If the individuals of that host species become scarce it must follow that either the individuals that remain must become more extensively infected, laying still further burden on the species, or the parasites themselves must become reduced in number. Hence although man can have little direct control of parasites affecting marine species, he may, indirectly, have much to do with the control of their numbers and their distribution.

Of the larger predatory forms, the

shark tribe, with the ubiquitous dogfish as the most common representative, is most conspicuous. It is true that of late years these have been hunted to be used for fish meal, oil and fertilizer, and in the case of the larger sharks, the skin for leather, but even yet the destruction does not keep pace with that of the common food fishes.

In some respects worse than the dogfish, for it will attack anything in the sea from a whale to a minnow, is the killer or *Orca*. Although in no way comparable to the dogfish in numbers, its size and its extensive field of action to some extent makes up for this. Although it makes inroads in nearly all the species sought by man, from the smallest to the largest, no organized attempt has been made to get any definite idea of the harm it does, or to prevent the continuation of its depredations.

The sea lion and the hair seal might be placed in this category, although, as has already been stated in the case of the sea lion, their effect on the life of the Pacific may not be wholly bad. They have been hunted at times and some satisfactory attempts have been made to utilize the skins. The difficulty in retrieving the bodies has been the chief reason for the general neglect in this regard.

There are many smaller predatory forms, *e.g.*, the sculpins and the lamprey, that must make a great difference in the life of the sea, in the toll they take of the young or the adults of other species, but data on this are almost wholly lacking.

Modifications due to the Changing Conditions in the Sea and along the Shore

Worse than exploitation, because even to man there are no compensating returns, is the destruction of marine forms by changing the physical and chemical conditions of the portion of the sea or shore that has been their habitat. Under this head the main feature is what may be included under the general term, pollution, by which the extent of damage has so greatly increased in the last decade or two. More than in any other way this increase has been due to the introduction of the use of liquid fuels for power boats and for industrial concerns generally.

When crude oil, distillate, gasoline or other similar substances are set free on the surface of the water, a film is formed that may spread over a very wide area, and, particularly in the case of crude oil, when the shore is reached, the whole intertidal area becomes affected. A portion may mix with the sea water or become dissolved in it, and this may be directly poisonous to many of the smaller forms, thus affecting the flora and fauna directly, and since these small plants and animals form the food supply for larger animals, it is likely to affect the welfare and possibly the distribution of these as well. The film on the surface may directly destroy the surface forms by poisoning, but it probably does so more extensively through suffocation, as the film prevents the absorption of oxygen from the air by the surface layers of water.

In a purely mechanical way, in the case of the crude oil again, the wings of birds are clogged and smeared, so that, in many cases, flight is impossible, and since flight is necessary in obtaining food, the birds starve to death.

The intertidal film along the shores has a destructive effect on the plants in the area and hence also the animals that depend on these for food or shelter, as well as directly on the animals themselves.

Beside the destruction caused by liquid fuels and their combustion products, deleterious effects are produced by setting free harmful chemical substances, as by-products of industrial works, sewage and drainage. The effects are similar to those from fuels, although in general they are more local. They are so

numerous, though, that the full effect on the whole coast is very extensive.

Dredging to deepen harbors and waterways destroys the local fauna and flora abruptly. If the dredged material is dumped farther out to sea, as it commonly is, there is a double destruction. The sluicing of land into the sea has a similar effect. Even the deposition of a thin layer of silt may be sufficient to destroy some of the more delicate organisms. A change in salinity, acidity or alkalinity, turbidity or oxygen content may destroy some or drive others away. Even as mechanical a procedure as towing logs may produce detriment, because in shelters where tugs with booms are wont to lie during stormy weather, enough bark sinks to the bottom to make practically a continuous layer, which of necessity disturbs the inhabitants of that area.

Changing Conditions that affect Anadromous Species

Somewhat akin to the changing of conditions that affect species in the sea and along the shore is the changing of conditions that affect anadromous species while they are away from the sea. The effect has been noted more particularly in the various species of Pacific salmon and in the steelhead trout, but is the same in type for all such species.

The main interference with natural conditions is in the placing of obstructions to either the upstream or downstream migration. Until recently the main obstruction to the upstream migration was the log jam, for which man was not always responsible. Of late much more efficient obstructions are being placed in the water courses, dams to retain water for power or irrigation purposes. To make the obstruction less apparent, in some cases "fishways" of various types have been introduced.

These dams serve as an obstacle to downstream migration as well. The taking of water from the rivers and streams for irrigation purposes provides many blind alleys for the migrating fry or young fish. More or less effective screening serves to decrease the mortality from this cause. Pollution produces its deleterious effects here, as it does in the sea and along the shore.

Man, on the Pacific coast, long since realized that these anadromous species could not stand indefinitely the drain on them in sea and river. To offset this drain, and perhaps also to salve his conscience, he tried fertilization, incubation and rearing under control, hoping thereby to reduce the loss in early life.

The Introduction of New Species

Finally a word is necessary on the introduction of new species. We have not been very prone to experiment with the introduction of new marine species on this coast. Is it because we think it difficult to improve the species we have already?

The most conspicuous success in introducing new marine or anadromous species on this coast, or possibly anywhere, is that of the shad. Pretty well fished out in all the eastern areas, where it was indigenous, it has developed so well in its adopted habitat that it provides for a fishery greater possibly than the original fishery ever was.

Perhaps even more extensive but not so conspicuous, because the species is not used for food here to any extent, is the distribution of the soft-shelled clam, *Mya arenaria*, which, since its introduction into the San Francisco bay region from the Atlantic coast, has spread, accidentally or incidentally, until it is now to be found in suitable locations along the entire coast.

Not so successful has been the attempts to establish other species. The Atlantic salmon, the Atlantic oyster, the Japanese oyster, the lobster have all shown indications that satisfactory results might have been obtained if the

attempts to establish them had been a little less haphazard and a little more definitely controlled. Whether it is advisable or not to introduce foreign species is quite another proposition. The more an introduced species thrives, the greater must be the disturbance among the species already there, even if it means only a struggle for food supply. If the introduced species is predaceous, it makes matters so much the worse.

Besides the species that have been introduced intentionally, others, not always desirable, have been brought into the North Pacific area in company with various structures, such as ships, used in transportation, or in structures, such as log booms, themselves transported over the sea. Of these certain marine borers have thrived so well that they have modified conditions directly and as well have modified very materially some of man's modifications.

Summary

To summarize, it may be said that the modifications in the life of the North Pacific, due to man's influence, have, on the whole, not been beneficial to the inhabitants of the sea or of its shores, and in many cases have not been in his own best interests. Many species have been exploited to depletion or extermination for temporarily abundant gain, when by reasonable methods of restraint in conservation a permanent source of supply would provide for less immediate gain, but one much more extensive in the long run.

By the destruction of these species in such numbers, while leaving more predatory species to increase, largely undisturbed, the natural balance has been materially affected.

By polluting the waters and by otherwise changing the conditions of the sea and the shore, areas, once fruitful, have been made desolate and barren.

Even this does not suffice, for the species that escape from the sea and enter the rivers to spawn are obstructed in their inward migration, and they or their offspring in their outward migration as well.

Species from other parts of the world have been introduced. The more lustily they thrive, the greater must be the disturbance among those species that have occupied the habitat that these now take for their own.

There are some indications that man is not wholly callous in regard to these effects. He will still make use of the harvest of the sea. We could not expect it to be, nor could we wish it were, otherwise. He is beginning to realize, though, that a permanent supply from which a fair proportion may be drawn annually is a better proposition than a rapidly decreasing supply that may give out even in his day and that will leave nothing for the future. He is beginning to believe in the necessity for conservation, even if in the most of cases he wishes it to apply to the other fellow rather than himself. He is beginning to see that regulation looking towards conservation, to be satisfactory, must be based on full information concerning the life history of the species under consideration, and at least theoretically, he is willing that support should be given to the investigation necessary to obtain that information. This serves as the basis for national and international cooperation in working out proper bases for conservaiton, which cooperation is already bearing fruit.

Although a balance similar to that which obtained before man interfered will never be, can never be, restored, we may look forward to the time when another balance will be maintained, such that man may take an annual toll from the particular species he may desire without materially decreasing, from year to year, the total supply in the sea—that is to say, that he will take only a number or quantity equal to the natural annual increase.

RADIO TALKS ON SCIENCE[1]

RADIO TRANSMISSION OF MUSIC

By Professor DAYTON C. MILLER
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In a lifetime devoted to the study of science, the phenomena of radio broadcasting stand out as the most marvelous of experiences. Personal interest ran through such wonders as the steam-engine, telegraph, telephone, polarization of light, X-rays, radium and wireless telegraphy. Perhaps the most fascinating pastime is to sit before the radio receiver, as in my home in Cleveland, and at will to hear music from one or another of the local stations, or from Pittsburgh or Detroit, or at one's caprice to tune in Boston, Dallas, Denver or even Oakland or Los Angeles at distances of more than two thousand miles.

Wonder is often expressed that we can hear from such great distances, but to me this is not the great marvel. While I am fascinated with the distance-getting, I am awestruck and overwhelmed with amazement when I hear the Symphony Orchestra in New York or St. Louis with such perfection and delicacy of intonation that it seems that I must be in the auditorium with the orchestra.

Who of us can comprehend and fully appreciate the processes by which an orchestra pleases us with its music? Some performers draw a few horse hairs across pieces of animal membrane stretched on boxes, others blow into tubes of metal or wood. Each instrument produces a complex sound wave in air, and the composite of all these waves reaches the ears of the auditors, quietly seated at a distance of one or two hundred feet, who receive sensations of exquisite pleasure (or pain). We can not see the medium or mechanism of transmission in this case any more than we can in radio. We know that the air is the medium of transmission and that it is of such a nature that the sound waves passing through it are quickly "damped" out, and this limits the distance of practical transmission. But space seems to be filled with another medium, which we may be allowed to refer to as "the ether," and which transmits electromagnetic waves a thousand miles more easily than air transmits sound waves a thousand feet.

In the concert hall the extraordinarily complex sound waves fall upon a circular piece of sheet metal, which one might crudely liken to the cover of a tin can; it is technically the diaphragm of the microphone transmitter. In my home the beautiful music of the orchestra is given out by another simple piece of sheet iron, another tin can cover! Certainly, there is much complicated apparatus between the two can covers, but it remains true that all I hear comes from the simple little circular piece of sheet iron. I hear the flute, the trumpet, the quartette of strings, the oboe and bassoon, the drums and bells, and in the complex parts these can be distinguished, each with its characteristic tone-color, when all are sounding at the same time. How can the little piece of tin reproduce the smooth tone of the flute, the strident

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and Science Service and the direction of W. E. Tisdale.

tone of the oboe, the majestic pomp of the trombone, and the beautiful harmony of the many stringed instruments, so that one thinks he is listening to a hundred instruments being played by a hundred of the world's greatest artists! This is a thousand times more marvelous than that signals are sent over distances of hundreds of miles.

In the studio of the sending station, the original sound waves fall upon the diaphragm of the microphone. This diaphragm never responds in exactly the right proportion to each and every kind of vocal and instrumental sound wave and combinations of sound waves. The movements of the diaphragm are not accurate representations of the original sound, that is, the wave has suffered a change of form in the instrument, which is called "distortion." The movements of the diaphragm are next transformed into electromagnetic waves, and in this process further distortion is introduced. In fact, every time the wave passes into a new medium or instrument, it suffers more or less distortion.

The electromagnetic waves from the microphone are amplified through an elaborate system of electrical apparatus, that is, they are magnified and lifted up into the ether, and are sent out from the station antenna as powerful electromagnetic waves in the ether. Such waves, after traveling great distances, are very weak, much too feeble to operate a receiving telephone. They can be detected only by means of a complicated receiving set, in which they are amplified; usually there are repeated amplifications. Finally, in the telephone "unit" of the loud-speaker the electromagnetic waves are transformed in the inverse order into actual movements of a diaphragm, impressing the wave-form on the air which passes to the ear of the listener. At every step of this elaborate process there is a lack of perfect response to the impressed force, and distortion is introduced again and again. Much experimenting has been done to prevent distortion and perhaps even more to correct it after it has been produced. Corrections are made by means of condensers, resistances, etc., applied here and there in bewildering confusion. These distortions are heard as a growling background in some voices, or as a shrill sound in other voices; as a predominance of high-pitched sounds in music, producing the effect of a drone which becomes very monotonous. Sometimes the distortion is so great that enunciation is indistinct and spoken words are understood with difficulty. Orchestral music lacks tonal balance and a proper tonal foundation. The crackling noises of static are especially exaggerated and annoy the listener.

Perhaps the least understood and most abused acoustic feature of radio receiving is the so-called "horn" of the loud-speaking telephone. Many inventors and manufacturers seem to think that the material horn itself is the essential thing, but it is not so. The horn is simply a shell that separates a certain quantity of air of a certain shape from the general mass of air filling the room in which the loud-speaker is located; the thing of acoustic importance is the cone of air contained inside the horn. The small end of this cone of air rests on the center of the diaphragm of the receiving telephone and constitutes what, in analytical mechanics, is called a "load" on the diaphragm. The air in the horn is disconnected from the main body of air throughout the length of the horn; it is thus an elastic body capable of its own independent vibration. At the open end of the horn it connects with the air in general. The loud-speaker may be likened to an acoustic broadcasting station, in which the air in the horn is the antenna.

The back-and-forth movements of the diaphragm which are produced by the

electromagnetic devices must, in a loud-speaker, be communicated to the air in the auditorium with a considerable increase in the amount of energy radiated, as compared with a simple ear telephone; that is, the sound must be "amplified." This amplification results from the reaction on the diaphragm of the column of air contained within the horn. With the horn attached, the diaphragm is "loaded" and does more "work" than when unloaded, just as a motor delivers more energy under load than when running light.

Unfortunately, vibrating bodies, such as diaphragms and air columns, have natural periods of vibration; that is, they vibrate more easily at certain frequencies than at others. If a complex set of vibrations is impressed upon the system, it will usually respond in greater degree to those components corresponding to its own natural periods, and these components will be exaggerated; this is called resonance. Sometimes the vibrating system refuses to respond to certain frequencies or to frequencies beyond certain limits; this results in certain component sounds being absorbed or filtered out of the composite. Sometimes the composite vibrations will cause some part of the system to vibrate in its own natural period when there is no component of this frequency present in the original sound. All these effects result in a distorted wave-form.

When the air-column in the horn is made to vibrate in response to the movements of the diaphragm, what are called stationary air waves, with nodes and loops, are formed. It follows naturally that a short horn, enclosing a short column of air, can not respond to sounds of long wave-length. The sounds of speech of a baritone voice contain component waves having a length of ten feet or more, and orchestral music contains sounds having waves twenty feet or more in length. A short horn can never give an adequate reproduction of such sounds.

While it is not possible to secure all the desirable effects and to avoid all the undesirable ones in the design of a horn, yet much better results can be secured than are usually obtained by the loud speakers in common use. It is at once evident that it is not the material of the horn itself that is concerned; it is the column of air inside. It is necessary that the walls of the horn should enclose a column of air of the desired shape, volume and length, and that it should permit of the freest possible vibration; beyond this it should have no effect. In order that the diaphragm may deliver its energy most effectively, the small end of the horn should be small; it should not be too small, else the long slender tube of the throat will introduce friction and obstruct the free vibration of the air column. In order that the energy may be properly distributed over the auditorium, the large end of the horn should be relatively large. Theory indicates an inconveniently large opening, and in practice a compromise, with a smaller opening, is generally adopted.

In the physical laboratory of the Case School of Applied Science, in Cleveland, there has been developed an instrument called the Phonodeik, which makes photographic records of the forms of sound waves; this provides a most excellent means of determining the acoustic efficiency of a loud speaker. A set of eighty standard organ pipes covering the range of the usual musical sounds of frequencies from sixty-four to forty-one hundred is used. Each pipe is sounded separately in front of the Phonodeik and a photographic record is made of what we may call its normal tone. These pipes are then taken to another room, out of hearing. Each pipe is now sounded in front of a regular microphone transmitter such as is used in broadcasting. The electromagnetic waves are conducted by

wire to the loud speaker in front of the Phonodeik, where the pipes were first sounded. The reproduction of each pipe by the loud speaker is again recorded by the Phonodeik. In this way it is possible to compare the results given by different loud speakers and by horns of different designs on any one loud speaker. Such experiments have been made for various types of instruments and for horns of many designs. The records clearly show the resonances, distortions and limitations of the various devices.

These investigations show that the exponential horn, that is, one in which the increase in cross-sectional area is uniform throughout its length, is distinctly better than a conical horn or one of the so-called "morning-glory" type; preferably it should be straight; it should be at least eight feet long. Probably metal is the best material, the inside being smooth and polished and without obstructions of any kind. Many trials with such a horn indicate conclusively that speech is more natural and music very much more musical. The richness and tonal body of orchestral tone-color is reproduced marvelously well. To appreciate these effects one must listen to a loud speaker equipped with such a horn.

There is very little that the amateur or individual user can do to remedy the remaining deficiencies in radio transmission. The conclusions reached from theory and from laboratory experiments are rarely directly applicable in commercial products. But I wish to assure you that there are many eminent and very competent scientific investigators continuously carrying on researches of the most profound kind to discover improvements in radio methods and apparatus, which will be made available by the great manufacturing establishments. Wonderful as is the perfection attained in radio broadcasting, we must remember that it is but an infant in years. I feel confident from personal knowledge of conditions that in the not distant future there will be radio apparatus which is simpler than that now in use and in which the transmitters, detectors, amplifiers and loud speakers will perform with much less distortion. We shall hear speech and music from great distances with such perfection that the hearer would be quite unable to detect any difference between the original speaker and the reproducing loud speaker, or between the symphony orchestra as heard in the listener's home through the radio receiver. When this is accomplished, our thanks will be generously extended to the radio scientists and engineers.

PROPHECY OF A CHEMIST

By Dr. WILLIAM J. HALE
NATIONAL RESEARCH COUNCIL

We live in a chemical world and our daily life is just a little group of chemical reactions under proper coordination. In order to gain a clear insight into the future of this chemical world we are forced to enter upon considerations exclusively chemical and physical. Even here our views may easily be distorted unless we can secure a second position for our observations, namely, that of the open mind. This position in triangulation may be looked upon as one projected into space. In this second position there must be absent from our

minds every trace of those inheritances from a darkened past with its superstition, sentimentality, religious bigotry and political bias. Thus, between these two views we shall surely see ahead, no matter how so little, but surely in proper perspective.

This power of looking ahead with chemico-physical biological interpretation and without mental hindrance of any sort may well be described as a new sense and certainly as ideal scientific vision. Many men of the past have clearly shown in their writings that they possessed no small degree of scientific vision, but their teachings were branded as heretical and heresy was then a thing to be reckoned with. To-day, even the term itself is cloaked in obsolescence.

To many of us who revel in chemical and physical data the happenings of the day are viewed with not much more than flitting fancy, for we realize that they soon must give way to bigger and better things. Let us then call up a few of the present-day pictures and project them into the future in order that possible comparisons may stand out more decidedly in contrast.

The greatest chemical discovery of the past few years is the Patart process of alcohol synthesis from carbon monoxide and hydrogen under higher temperatures and pressures. Speculation is rife on the possible development of this process. From a broad viewpoint, however, the story has scarcely begun. New syntheses involving carbon monoxide, carbon dioxide, hydrogen, ammonia and other gases are soon to introduce a vast array of oxygenated and aminated hydrocarbons of incomparable value. Thus organic chemistry stands at the threshold of a future so vast and with such ramifications as to surpass our wildest dreams. We may safely predict that the greatest developments in the very near future will lie directly in the application of physical chemical principles to the science of organic chemistry.

The study of catalytic processes is receiving constant attention and yielding results of greatest value. Thus, crude petroleum and shale oils will soon be made to yield a very high percentage of low boiling hydrocarbons of unsaturated type. When these are admixed with the alcohols of the Patart process we shall have our new motor fuel. Those who fancy automobile manufacture to have reached almost its saturation point for home consumption little know the future in store for the auto bus alone. Railroads will operate countless busses paralleling their lines as local carriers, leaving to the railways the through passenger and freight traffic. It is not at all unlikely that, for these motor busses, and close to the railroad lines, will be laid a type of rail-bed composed of waste from sugar cane and corn and other grains, together with binding material. Furthermore, steam locomotives will eventually be replaced by the electrified type, but in the meantime a great step in advance over the present, with a saving of 25 per cent. of fuel, may soon be consummated by the installation of the bi-fluid type of engine.

The aeroplane is destined primarily for rapid transit. New types or combinations will make the aeroplane just as safe as a parachute, for it will be immediately convertible into such at a moment's notice. Alloys of magnesium and aluminum will certainly constitute the entire structure of the plane proper and the assured possibility of very high compression in the explosive mixtures for the motor will make for increased efficiency and power. Such development of the aeroplane will arise more economically through commercial enterprise and thus we hope that many aero-transportation companies will soon be in operation.

The use of the aeroplane in possible war is, of course, of primary importance to any self-respecting nation. The old adage, "Be not the first by whom the new is tried, nor yet the last to lay the

old aside," was never more decidedly banal than it is to-day. Possibly there is an old-fashioned kind of pride in beholding one's country's beautiful battleships ploughing gracefully through the mighty deep, but here assuredly is that political bias asserting itself. Such ships are practically useless in battle and worse than useless in self-defense. The chemists have sealed the fate of such and the aeroplane is the means of inflicting the mortal wounds. You read of controversial matters relating to the possibility of blowing up a battleship with aeroplane fire. It makes good reading, but in the wars to come no such harsh treatment will be administered, for the enemy will adopt the newer methods and quietly incapacitate the occupants of these ships in the darkness of night and seize the boats for preservation in their museums, as illustrative of that form of weapon once used in the period of cumbersome warfare.

Naturally, every rational man must ask himself the why and wherefore of building battleships. It is only a sop to the national pride of those who can not throw off sentimentality and immediately grasp the new. Science progresses steadily and can not be stayed. Inside of ten years only the speediest cruisers, aeroplane carriers and submarines will constitute the backbone of the navy, and the aeroplane will be the strongest arm of both the navy and the army. One of the saddest commentaries on America, as a wideawake nation, is that those in authority have not now the courage to follow the advice of scientific men as well as popular opinion and scrap every battleship in our possession and direct that the moneys so saved shall be expended in every form of research that may bear upon the development of aeroplanes and air travel. It is just now coming home to us what Germany has been able to do in the way of discovery and invention when forced by the allied nations to turn her attention from the folly of building and maintaining battleships and to apply herself to industrial research.

With this development of rail and air carriers the biggest factor, the farm, must also claim our consideration. So much is heard of the farming industry and of the depressions it suffers that we begin to wonder why all this furor. Only twenty-five years ago we were a nation of miners, shepherds and grain growers, supplying products to foreign countries where through cheap labor these products could be converted into manufactured goods and as such resold to us under no greatly enhanced price. The farm wastage per acre was insignificant then in comparison with the profits and especially so when the dollar had a greater purchasing value. To-day we have become industrialists. Through a decrease in the purchasing value of the dollar, labor naturally requires higher wages and the price of manufactured goods also soars. The industrialists, therefore, are constantly forced to decrease their manufacturing costs and this decrease strikes first and most severely the dealers in raw material—primarily those particular commodities coming from the land.

Now that the farmers have been drawn into this same industrial whirl they must also readjust their operations accordingly. It is just as necessary for them to avoid overproduction as it is to install proper storage and avoid wastage. The farmers must enforce lower cost of production, steady sales and rapid delivery just as any modern industrial institution, and yet how many of our farmers realize their transformation into industrialists. If there is any blame to be meted out, it must be meted out to the farmer himself. His has been a glorious existence in bygone days—the cradle of America's independent thinker and citizen; the backbone of our democracy. We would not disturb this ideal status.

We would only glorify it the more. Let us then dismiss sentimentality and look upon each other as what we are—parts of an enormous industrial unit where there is no independence or rest until the day we retire.

We read of all sorts of suggestions for the betterment of the farmers and the best of these is the so-called cooperative marketing, commendable in itself and certain to benefit those who participate. But why grasp only one horn of the dilemma when we can take it all bodily and become master of the situation. Cooperative marketing is good; so also is cooperative purchasing. But cooperative farming comprises every activity and when groups of these small industrial units, the farms, are placed under scientific management, then, and not till then, shall we see the metamorphosis of the farm into that of a new and greater power, the home of bliss and content.

Time was when the gross income from a small farm constituted a relatively large return on the investment. This return might still obtain, even on the greatly enhanced value of the land, but the operating expenses have curtailed the possible net income to a point where scarcely more than living expenses remain for the farmers. We can not eliminate competition without wrecking the bulwark of civilization. There remains the direct necessity of curtailing overhead and operating expenses and thus increasing the net income to the farmer. The single farm is entirely too small a unit upon which such curtailment can make an appreciable effect. The operation of farms in groups, however, will admirably serve this purpose. Individualism will still remain, but it will be typified in a group or family rôle and the process may be described as merely a step up from our present-day family of five to one of five hundred. This is the trend of all business and of all industry in general.

It is interesting to watch this modern trend and note, for example, that of the annual crop of three billion bushels of corn already 15 per cent. leaves the farm for manufacture. The day will come when 50 per cent. of it will come into the industries and the by-products will return directly to the farm for the fattening of stock. The oat-hulls and corncobs of to-day are just beginning to come into industrial use. It may seem a far cry to us that we shall raise oats for the oat-hulls and use the by-product, or kernel, in cereal manufacture, but that day is surely coming and coming soon. Main products and by-products are interchangeable terms in the parlance of the industrialist. They are not so with the farming industry, and hence, if we would bring the farming industry into the first rank, we must introduce likewise every new phase of economic efficiency.

Since the dawn of this new industrial era our exports of raw material have shown appreciable decline. To prophesy fully, we ourselves shall be importing grain within ten years and selling enormous quantities of finished goods abroad. This is the natural consequence of efficient manufacture. Simultaneously, there will follow, through keener and keener competition, a lowering in price of finished article to that point where profits can accrue only through mass manufacture. The prosperity of the industries spells likewise prosperity to the farmer, but with the absorption of more and more products from the farm into the home manufacture it becomes evident to all what a cataclysm to the farmers will be registered by any depression in our industrial activity.

Our manufacturing industries are flourishing to-day as never before. Some, of course, will fail where foresight and research are absent, but such should fail by all the laws of science. It is only the most wideawake organizations that can

forge ahead. New processes and all possible combinations are ever emerging and taking effect. Products made for years by old-time processes are meeting with such innovations as would shock their first discoverers. Chemically speaking, our processes are just entering a new régime, a régime first inaugurated by the Haber ammonia synthesis and more recently by the Patart and other processes. The future so far outdistances the present in the scope and breadth of its utilization of every known thing that what calls for your approbation and wonder to-day will serve only as of insignificant historic interest in the days to come.

For these enormous developments that await us, one of the greatest requirements is that of power. Water power will come into greater and greater development, but all the water power in this country can not give us more than fifty million horse-power. We must, therefore, look elsewhere, and here the visualization of the future at greater distance seems most appropriate. The sun's rays are the source of all power to-day, whether it be direct or indirect. The sun's rays, too, will be the source of power in the future and with much of the indirect sources rapidly nearing exhaustion we shall turn to the sun itself and through chemical means involving complicated reactions bring this energy under control. The economical photosyntheses now being studied are of more or less complicated nature, but it is safe to say that they require not only a high degree of sunlight but contiguity to large bodies of water—such ideal conditions as may be found on islands in the southern waters between here and South America.

We read in the papers of the foreign financial obligations to this country. Many are the pages and lengthy is the treatment given, but never has been heard an open scientific discussion of the problem. Political bias decrees that such matters be left to our posterity where the rôle of necessity may, if it will, enforce itself. Preparedness is a harsh mistress, and not many can cope with her. If only our public men could cast off all sentimentality and diplomatic deference and enter into these dealings upon a strictly chemical basis, what a grand opportunity to help both ourselves and our friends across the sea! A number of the possessions of France and England in the southern seas will undoubtedly come into value for us within twenty years. To-day they have no value for us and but little for either France or England, but when we shall have to purchase these possessions, as will surely come to pass, we shall be only too glad to pay a sum equal to, if not in excess of, the entire foreign indebtedness to us. Why not make the deal now and wipe out foreign obligations, thus stabilizing both financial and economic relations between Europe and America? In the past others high in public life have acted in a similar manner and wisely. Who to-day would question the wisdom of the purchase of Alaska? The course of progress indicates that southern countries must come into development for many of the new industrial activities, and by acquisition of certain of these possessions that can come into present-day consideration we are only building for our successors.

Many may question why chemists, physicists and biologists are particularly endowed with a sort of ultra vision. Since the early days of alchemy it appears that this has been a trait of those skilled in the manual arts. One need not qualify as an expert in any of these sciences, but he must be schooled in chemical, physical and biological laws if he would be able to weigh accurately the events of everyday life, for are not all these events just the results of life processes—which in turn are governed by

these laws? From such scientific viewpoints triangulated with one far distant from human frailties what a wonderful picture our observers may behold of the mighty and magnificent future that awaits us and our posterity.

THE FIXED NITROGEN RESEARCH LABORATORY

By Dr. S. C. LIND

ASSOCIATE DIRECTOR, FIXED NITROGEN RESEARCH LABORATORY

MANY of the radio hearers may not know that since the close of the late war, the government has maintained in Washington, on the campus of the American University, a laboratory devoted to the fixation of nitrogen. You will naturally wonder what is the importance of this one element that a laboratory with a staff of seventy-five or eighty men should be employed in the problem of capturing nitrogen from the air and of causing it to combine chemically with some other element which we call "fixing" it. You may imagine that the problem of fixing nitrogen is both difficult and important and that it has a new significance that arose from the war, all of which is true.

Nitrogen in some respects is one of the most baffling of our chemical elements. Its atom is the seventh lightest of all the elements, being preceded only by hydrogen, helium, lithium, berylium, boron and carbon. Its atomic number *seven* being odd indicates according to Harkins's rule that it should not be a very abundant element, and yet it constitutes four fifths of the volume of the atmosphere. This apparent exception to the rule is due to the fact that nitrogen does not form compounds of sufficient stability to exist in the earth's interior and therefore nearly all of it is concentrated in its free state in air. However, nitrogen does not constitute a large fraction of the earth's total mass, although abundant everywhere on the earth's surface.

The sluggishness of nitrogen in entering into compounds early gave an exaggerated idea of its chemical inertness. The French named it "azote," a word of Greek origin meaning "without life." Yet it is a very active and essential component of all plants and animals; it is therefore absolutely necessary in some form as a plant food. Since its inertness in the free state prevents it from being directly assimilated, it must first reach the plant through the soil in some combined or fixed form.

The nitrogenous matter normally present in all soils becomes depleted when the natural processes of the return of nitrogen are unbalanced by crop removal. This exhaustion of the soil entails the problem of artificially fixing nitrogen of the air so that it can be resupplied to the soil in some form of fertilizer.

Another great use of nitrogen compounds is in industrial and military explosives like nitro-glycerine, tri-nitrotoluol, gun cotton, dynamite, etc., all of which require nitric acid, an oxidized derivative of nitrogen.

The principal sources of nitrogen compounds, besides those in the soil, are coal and Chile niter. A vast total quantity of nitrogen is stored in coal and may be obtained in the form of ammonia when coal is distilled to make coke or coal gas,

but the nitrogen content of coal is low, one half to two per cent., and of this only about five pounds of nitrogen per ton of coal are recovered in coking, so that it is not profitable to mine and distil coal for nitrogen alone. The coke and gas industries can not supply more than half of our nitrogen needs. Chile niter, or nitrate of soda, a natural salt occurring in Chile, has until recently supplied most of the balance, but it is a highly localized source of supply, not dependable in time of war, due to difficulties in its production, export and transportation.

The only remaining alternative is the nitrogen of the air. This source is tremendously large compared with the others, ten to one hundred thousand times the total tonnage in coal and Chile niter combined, and yet prior to 1905 this vast and universally available storehouse had never been tapped except through certain processes of nature which we have not yet learned to imitate. It recalls the familiar story of "water, water everywhere, but not a drop to drink." We are surrounded by nitrogen, it constitutes three fourths of the fourteen pounds of weight pressing on each square inch of our bodies and four fifths of the volume of air we breathe. We inhale and exhale a weight equal to that of our entire bodies every five days, but, as far as we know, the lungs fix no nitrogen and it leaves us again a complete stranger. Without artificial fixation processes the human race, though living at the bottom of a sea of free nitrogen, would sometime be faced with the danger of nitrogen starvation.

Just before the war Germany solved the problem of cheap nitrogen fixation. In fact, a close connection has been alleged between this discovery and the beginning of the war, for it at once made Germany independent of Chile niter for war explosives and insured nitrogen fertilizers for her soil. Just before and during the first year of the war the tonnage of fixed nitrogen in Germany reached two hundred thousand tons per annum, or nearly equal to our present total use of it in fertilizers. At the close of the war the German tonnage had risen to three hundred thousand tons per annum, and has since been increased to four hundred and twenty thousand tons, or nearly twice our consumption.

Nitrogen fixation is now being studied and applied throughout the civilized world. It has become a form of international competition which we can not ignore if we would. The United States on entering the war established two plants at Muscle Shoals, one designed for five thousand tons per annum, to operate under a modified German process, and the other for forty thousand tons, to operate a method which had been successful at Niagara Falls, but which was tending toward obsolescence through the introduction of the newer process. Two things were clearly shown by the experience obtained up to the time of the armistice; first, that we were not sufficiently acquainted with the German process to operate Plant No. 1 at Muscle Shoals successfully, and second, that the larger or cyanamide plant might in peace-time become a perplexing problem through not being directly adaptable to peace-time needs. Operation of both plants was deferred and no further disposition has been made of them as yet.

In 1919, the War Department decided to devote part of the nitrogen fixation funds to a fundamental study of different processes, and accordingly established the Fixed Nitrogen Research Laboratory in Washington. In 1921, the laboratory was transferred to the Department of Agriculture, as it was evident that the peace-time use of fixed nitrogen in fertilizer represented the dominant need.

The laboratory was endowed with sev-

eral different functions—one to become acquainted with all the methods of nitrogen fixation, and to make this information available to our government and to the industries. Second, to provide by observation and experiment a basis of decision as to what processes are best adapted to American conditions.

Prior to the development of the German or Haber process, there had been two principal processes in use, each having its own peculiar advantages.

The arc process, which had its earliest development at Niagara Falls, first became commercially successful in Norway. It consists in passing air through the electric arc, which, in virtue of its extremely high temperature, causes a small part of the nitrogen and oxygen of the air to unite directly to form oxides of nitrogen that can readily be converted into nitric acid and nitrates, useful both as fertilizers and explosives. Owing to its excessively great consumption of electric power the arc process has not been generally applied outside of Norway, where huge quantities of hydro-electric power are to be had cheaply. Although there is no immediate hope of the revival of the arc process in the United States, the direct union of the nitrogen and oxygen of the air in some economical way is so desirable and has such patent advantages that it will some day be accomplished, and until then it must remain one of the outstanding problems of the Fixed Nitrogen Research Laboratory.

The cyanamide process had also been developed at Niagara Falls and was put on a successful commercial basis as early as 1908. It was therefore possible for the government to secure the cooperation of an American company to install its process at Plant No. 2 at Muscle Shoals. This process also involves the use of rather high electrical power, although much less than does the arc process. The product, cyanamide, may be converted to other nitrogen products or be used in mixed fertilizer to correct soil acidity. The latter use is a definitely limited one in this country, and it is still an unsolved problem to provide additional outlets for cyanamide products, either as fertilizer or in other ways.

The third and now most important process is the German, or Haber, process, involving the fixing of nitrogen by union with gaseous hydrogen to form ammonia, the salts of which can be used as fertilizer, or which can be oxidized to form nitric oxide, the same as the primary product of the arc process. The great tonnage of synthetic ammonia now being produced in Germany has, in spite of the early difficulties encountered in Plant No. 1 at Muscle Shoals, stimulated great interest in this country and kept up the hope that the process, already installed on a small scale by a few companies, will soon be expanded to a tonnage that will make itself felt in lowering the cost of fertilizer nitrogen. The Nitrogen Research Laboratory has, therefore, put its utmost efforts into mastering the intricacies of this method, so imperfectly understood in this country at the close of the war. The heart of the process consists in passing the gases, nitrogen and hydrogen, at very high pressures and fairly high temperatures (dull to bright red glow) over a substance called the catalyst, the function of which is to speed the rate of combination which would otherwise be too slow for commercial purposes. The catalyst body developed by the Fixed Nitrogen Research Laboratory has given good results under commercial conditions, and is now at least equal to that used in any other country. It consists of iron reduced from its fused magnetic oxide and contains about three per cent. of alumina and one per cent. of potash. The laboratory has worked out the mechanical and engineering details so as to operate at a considerably higher pressure than the German process, and has de-

vised many new engineering features of high pressure technique.

At present the United States occupies but tenth place among the nations of the world with respect to the fixation of nitrogen, and this despite the fact that we are the second consumer of total nitrogen. One small arc plant is in operation on the Pacific Coast. No cyanamide plant, except the idle one at Muscle Shoals, exists in the United States, but an American company is producing on the Canadian side of Niagara Falls. About a half dozen synthetic ammonia plants are now operating and others are soon to begin, which will give a total capacity of about ninety tons per day, but no single one will exceed a daily capacity of twenty-five to thirty tons. This is but a small beginning compared to Germany's daily production of fourteen hundred tons. But our position is quite different. Germany's installation was a war subsidy, which is now being operated to amortize the investment in these plants and to avoid having to import nitrogen. The European countries have much smaller steel and coke industries and hence less by-product ammonia, and are also remote from Chile niter, so they are more directly forced to develop their air fixation processes than we are. Necessity being the mother of invention, the German process was devised to meet a unique situation and is now not only being profitably operated but actually expanded at a rate exceeding new installation in any other country. Looking to our agricultural future, as our virgin soils become more depleted, we shall have to use more nitrogen fertilizer per acre, as in Europe, consequently we must augment our nitrogen fixation.

All indications point to a great expansion of this industry in the next few years. Catalytic processes under high pressures, which have now attained one thousand atmospheres, represent a radical innovation. Advances are certain to be rapid; and a vigorous research program is essential to insure the position of the United States in this branch of world industry. The strength of our position lies in the fact that we now have a knowledge of its technique, while we need not be stampeded into improvident or uneconomic developments.

Perhaps such concerted effort has never before been focused by all the civilized nations on the chemical technology of a single element. The Fixed Nitrogen Research Laboratory has formed a center in this country for collecting and obtaining information and engineering data necessary for the development of the nitrogen industry. Recently, in passing through the machine shops of the laboratory my attention was arrested by a striking operation. The barrel of a large naval gun was being bored out, to convert it into the catalyst chamber of a high pressure ammonia converter. This, as it struck me, is a twentieth century version of beating the sword into the plowshare. The transfer of the Fixed Nitrogen Research Laboratory from the War Department to the Department of Agriculture was but a larger expression of the same desire to turn one of the many liabilities of war into an asset of peace.

RELATIVITY AND LIFE

By "BETA"

I HAVE been criticized for attempting to write anything about relativity inasmuch as I am not a mathematician, but it seems to me that this criticism means that my critic thinks there is only one frame of reference from which relativity can be measured, namely, mathematics. But this is a denial of the fundamental thought in relativity. The germ of relativity consists in the idea that there is no one frame of reference from which alone reality can be measured. Does not this idea apply to relativity itself? Can not a man measure relativity from a non-mathematical frame of reference? This is what I am attempting in this paper.

I wish first to define the term absolutism. By absolutism I mean the theory that states there is one unique frame of reference from which alone reality can be correctly measured. Now relativity is not so much a new affirmation as a denial of the old affirmation absolutism. In the history of ideas there have been three great movements from absolutism to relativity. The first was in religion. The church claimed there was only one frame of reference from which to measure spiritual values, namely, the Old Testament as interpreted by the church. Luther introduced relativity or the right of private judgment. The next was absolutism in government or the divine right of kings. Democracy set up relativity or government by changing public opinion. The last stronghold of absolutism was in physical science, where it was long held that there must be one frame of reference from which alone length, mass and time can be correctly measured. Michelson tried to prove this with his measurements of the velocity of light and failed, and then came Einstein, who destroyed the last absolutism as Luther had destroyed the first.

Now it is the persistence of absolutism in life that causes most of our troubles. Is not the cause of social friction in this world due to the fact that most of us, consciously or unconsciously, are absolutists and will not look at things from any but our own frame of reference? The chaos in middle Europe is due to absolutism in the form of nationalism. I agree that nationalism is a very good frame of reference from which to measure some things. There are several very beautiful things in life which are well worth while and which nationalism sustains, such as art, literature, music, traditions and sentiments. But the trouble is that when we are absolutists we measure everything from one frame of reference. Now if there is anything certain in this world it is that political economy can not be measured correctly from a nationalistic frame of reference. Yet that is just what the people of middle Europe are trying to do and naturally they are making a mess of things. The trouble is that in spite of Luther, democracy and Einstein, the mass of mankind do not yet see that relativity and not absolutism states the truth about life.

Yet there have been men who for thousands of years have been relativists. I refer to artists. You will never hear artists claim there is only one way of expressing the beauty of life. The painter sees beauty in the statue and in

music, in prose and in poetry, in different forms of architecture; he admits they are all different ways of expressing the beautiful. But before Einstein, if a physicist had said that this thing called measured length is not an absolute but will vary according to the way you look at it (which, of course, is just what all artists say of art in general) what would have happened to this pre-Einstein physicist? It is an interesting fact that there has never been the slightest antagonism between art and religion, which is simply because artists are relativists, whereas the antagonism between science and religion was due to the fact that pre-Einstein physicists were absolutists, just like the theologians, and whenever there is absolutism there are always reasons for fighting. Einstein has left the absolutists in physics no ground to stand on. Yet absolutism will be a long time dying out, and I find absolutism as a philosophy existing (often unconsciously) in men who claim to understand relativity. The reason why Einstein overthrew absolutism is because he is not a scientist. Einstein is an artist whose medium of expression happens to be mathematical physics instead of line, color or marble. One has only to look at his picture to recognize the artist.

I wish now to make the following heretical suggestions. It seems to me that the difference between the living organism and the so-called non-living is not so much a difference in the "thing in itself" as it is in the frames of reference we use by which to measure it. Mechanism, which we think characterizes the non-living, implies repetition and hence predictability. But Einstein has shown there is no such thing as repetition in any real sense. We get repetition simply by choosing a frame of reference which will show it. Thus, a seconds pendulum repeats if the origin of our frame of reference is the point of support of the pendulum. But if our origin is in the sun, the pendulum will not repeat for at least a year. We can choose a frame with its origin such that we can never prove that the bob comes back to its original position. What then becomes of repetition and the so-called regularity of nature's laws? It does not exist in any absolute sense because we can not find a frame of reference at rest to prove regularity. We get regularity simply by agreeing to ignore the irregularities, and we do this by choosing the proper frame of reference. All that science has the right to say about nature is that it is generosity raised to the nth power. Nature will show us anything we want to see, provided we hunt with the proper frame of reference. The frame we choose is a function of the particular activity which interests us. Whenever we measure a phenomenon in science, our frame of reference must be outside the thing measured. This is the objective method of science, and a constant characteristic of this method is to ignore what does not interest us. So far as science is concerned, it continually measures parts, not wholes.

Now it happens that, being living beings, we have the power of measuring one whole, and that is our own psychical life, and what do we find here? We find creation going on all the time. We never find repetition in our psychical life so long as we view ourself as a whole. This is all that we mean when we say that we grow older day by day. Our second experience is always different from our first experience if only because it has in it the memory of our first experience. This must be true since otherwise how could we know the experience is a second experience? This of itself is convincing evidence of creation and a denial of repetition in our psychical life considered as a whole. But when we cut

ourself up into parts (a very different frame of reference) and examine the parts objectively, of course we find repetition, and hence, mechanism. Each living organism is a closed system to itself, and hence it must be compared only to a complete universe closed in the Einstein sense, in which there is always creation when measured as a whole, but which, of course, shows repetition when measured by parts, that is, objectively.

We have no direct conscious evidence of anything outside ourself, being as we are systems which are closed psychically. To this extent, Berkeley is right. Our consciousness does, however, give us good grounds for inferring the existence of other systems and it is this justifiable inference which has built up objective science. In the same way we may infer the existence of universes other than our own, but, if Einstein is right, we can have no direct knowledge of them. According to Einstein, try as hard as we may physically, nothing can get out of our own universe. Just so, according to Berkeley, try as hard as we may psychically, we never can get out of our own consciousness.

THE PROGRESS OF SCIENCE

DEDICATION OF THE PEABODY MUSEUM OF NATURAL HISTORY OF YALE UNIVERSITY

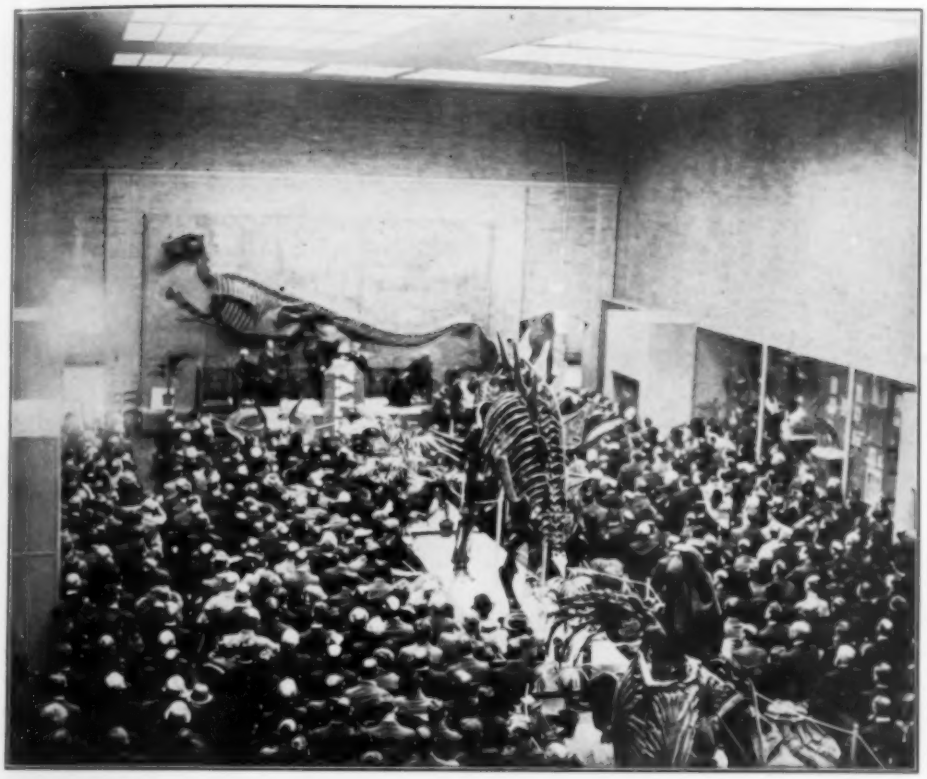
An efficient educational museum, thought Professor G. Brown Goode, "should be a collection of instructive labels, each illustrated by a well-chosen specimen," and circumstances have favored the application of that principle in Yale's fine new Peabody Museum.

Its old building came down in 1917 to add room for the Memorial Quadrangle. Its collections went into storage. Then America entered the war, and prolonged upheaval followed. Before the exhibits could be reinstalled in a new building, the anti-evolutionary crusade set in, to culminate at Dayton. Thus, when it became possible to resume activity, the museum had not only a new opportunity but a new responsibility—the responsibility, that is, of presenting evolution as a law instead of merely as a hypothesis. This, naturally, could best be accomplished by "a collection of instructive labels, each illustrated by a well-chosen specimen."

In his address at the dedication ceremonies on the 29th of last December, Professor Henry Fairfield Osborn, of Columbia University, quoted Baldwin's definition, "LAW: Any formulation of sequences which from demonstration, experimental proof, successful application, or for any other reason, are accepted as having a high degree of probability." All around Professor Osborn, as he spoke, were exhibits in which labels

DR. RICHARD S. LULL AND PROFESSOR HENRY FAIRFIELD OSBORN

DR. LULL, DIRECTOR OF THE PEABODY MUSEUM OF NATURAL HISTORY, STANDS ON THE LEFT. DR. OSBORN, PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY AND RESEARCH PROFESSOR OF ZOOLOGY AT COLUMBIA UNIVERSITY, STANDS ON THE RIGHT.



DEDICATION EXERCISES

THE AUDIENCE SEATED IN THE MAIN HALL OF THE PEABODY MUSEUM. FIVE HUNDRED SCIENTISTS ATTENDED THE CEREMONIES WHICH TOOK PLACE ON DECEMBER 29.

told the story of evolution and specimens substantiated it.

For the first time in America, scientists have the satisfaction of seeing the complete continuity of life illustrated by fragments of concrete reality, and a repetition of the Dayton uprising will hereafter be somewhat difficult. For this is not alone a museum for specialists in research, for scientists in the making, and for undergraduates in Yale College, but at the same time a museum for Yale divinity students, for the people of New Haven, and for children, with a special docent to guide the children through. Inasmuch as Yale has long been a pacemaker in education, it is more than likely that other university museums will soon begin to copy this one. Evolution will be popularized. Meanwhile, the exhibits at Yale are being photographed. The next agitator to stir up a fuss over evolution will find the photographs reproduced in the newspapers, and there the general public will see demonstrations of heredity, of variation, of adaptation and of the evolution of this or that familiar species—the camel, the elephant, the horse, and man himself. Also, some editors may venture to print photographs of evidences from embryology, for those, too, are there.

Evolution dominates the museum's entire lower floor, which is so planned that the visitor begins at the beginning and follows the argument through to its con-

elusion. According to certain remarks overheard at Dayton, he will then be a complete and finished atheist. As a matter of actual fact, however, there are no atheists among the museum's curators, and Director Richard S. Lull is a devout Episcopalian. In the course of his address at the dedication ceremonies, Dr. Charles Schuchert read Harvey Maitland Watts's religious poem, beginning:

> "Great God of nature, let these halls
> The hidden things of earth make plain;
> Let knowledge trumpet forth her calls,
> And wisdom speak, but not in vain."

Just how popular such a museum as this will be is of course a question, but every care has been taken to make it popular. Instead of confusing the visitor by confronting him with crowded cases, only significant specimens are shown—barely a tenth of what the museum possesses. The rest are stowed away down cellar, where the seismograph is installed in a region piled high with packing boxes, or they are arranged in drawers upstairs for use by research workers from all over the world.

Many of the exhibits have an inherent popular appeal — Marsh's dinosaurs, pterodactyls and toothed birds, for example, and the frequent "habitat cases," one of which gives a glimpse of a coal-age forest, while another shows a section of a coral reef with the corals painted in the colors of living polyps, and still another presents models of extinct marine monsters in what might almost be mistaken for real water.

As popular, manifestly, are Professor Lull's novel restorations of extinct animals. He explains them thus: "In the old days, when we had a fossil skeleton that was rather imperfect, we mounted it on a slab. I came to the conclusion that this was waste. Now what I do is to take the skeleton and mount it, and then model flesh on the poorer side of it, working from comparative anatomy of domestic animals, building up the flesh synthetically, and in that way work over the skin done in plastelline.

"After that, we generally leave it for a while for criticism, getting other scientists to tell us what they dislike in it, and proceed to manipulate it until we have attained what we want.

"Then the plaster mould is made. The bones are carefully cleaned and put in place, with irons run through the legs, etc., and plaster of paris is poured in.

"Instead of having only bones, we now have positive or flesh restoration on one side and bones on the other. On the restoration side, we at first used the color of the matrix in which the bones were found. Later, we decided that, as there were certain definite laws of coloration, it was fairly safe to paint according to what we thought the color was in life.

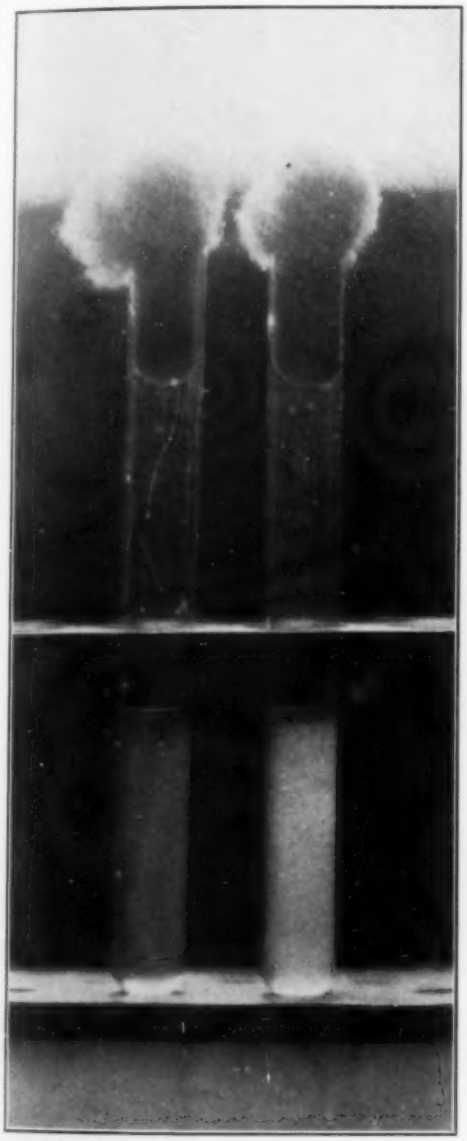
"Then we went still further, and instead of having one animal, assembled a group. From one side, you get a series of ghostly skeletons. On the other side, you see our interpretation of them—what the scientist has in mind."

A striking group shows a giant saber-toothed cat fiercely menacing a prehistoric wolf, and if the cat was not as tawny as the professor makes out or the wolf as silvery gray, it is difficult to prove it.

Upstairs, where the museum's famous meteorites, its superb cabinet of minerals, its ethnological exhibits and its collection of New England animals and birds are installed, evolution is not the theme illustrated. Will these upper halls be more popular on that account, or less so? It is difficult to judge. Just now they seem as popular as those on the ground floor, and if the stories connected with the Marsh collection are entertaining, so are the stories connected with the exhibits upstairs. One such story, retold on dedication day, immortalizes Thomas Jefferson's comment when he heard that two Yale professors had recovered fragments of a meteor at Weston, Conn. "It is easier to believe that two Yale professors will lie," he said, "than that stones fall from heaven."

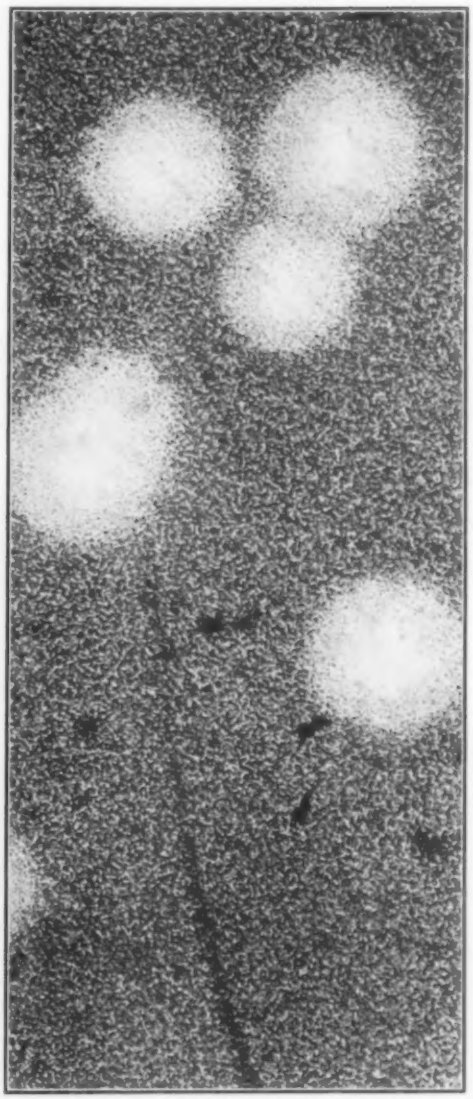
ON THE NATURE OF BACTERIOPHAGE

An article in the current issue of THE SCIENTIFIC MONTHLY entitled "Do Bacteria have Disease?" assumes bacteriophage to be endowed with life. This account presents d'Herelle's viewpoint and accepts the theory that it is a minute organism or an ultramicrobe. Do the facts warrant such an assumption? Not nec-



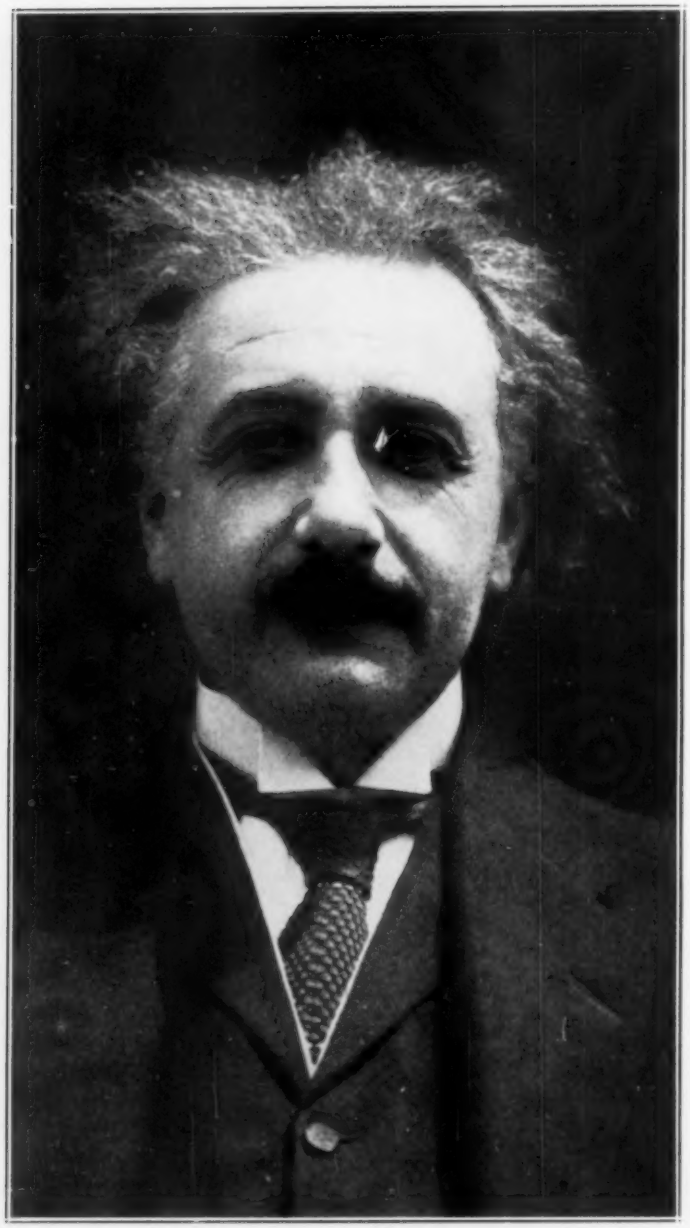
AGAR PLATE

ON THE RIGHT IS A CONTROL TUBE OF BROTH CLOUDED BY A DENSE CULTURE OF BACTERIA. ON THE LEFT IS A SIMILAR TUBE 18 HOURS AFTER THE ADDITION OF ONE PART IN 1,000,000 OF BACTERIOPHAGE.



TEST TUBES

SURFACE OF AGAR PLATE COVERED WITH A DENSE GROWTH OF BACTERIA. THE CLEAR CIRCULAR AREAS ARE VOID OF BACTERIA DUE TO THE ACTION OF THE BACTERIOPHAGE.



PROFESSOR ALBERT EINSTEIN

THE PHOTOGRAPH (COPYRIGHTED BY UNDERWOOD AND UNDERWOOD) WAS TAKEN AT THE TIME OF PROFESSOR EINSTEIN'S VISIT TO THE UNITED STATES IN 1921.

essarily: A large volume of experimental evidence, collected by various investigators, both here and abroad, suggests that the phenomena described by d'Herelle can be explained without the assumption of the existence of a living ultramicrobe.

According to these findings, the active principle responsible for the dissociation of bacteria may very well be a chemical substance which is a product of bacterial metabolism. While much of the evidence against d'Herelle's hypothesis is too involved and technical to be presented here, the following facts, if correct, have shown that the so-called bacteriophage possesses properties incompatible with life: (1) Bacteriophage does not respire; (2) it is not destroyed by repeated freezing and thawing; (3) it does not reduce methylene blue; (4) it is not destroyed by acetone or by 95 per cent. alcohol.

Whether the use of bacteriophage in the treatment of disease is destined to revolutionize medicine of the future, as claimed by d'Herelle, it seems important to determine its intimate nature.

THE AWARD OF THE COPLEY MEDAL TO PROFESSOR EINSTEIN

THE Royal Society awarded the Copley Medal to Professor Albert Einstein, of the Kaiser Wilhelm Institute, at its anniversary meeting on November 30. At the time of the award the following citation was made:

The name of Einstein is known to every one through the theory of relativity which he originated in 1905 and extended by a notable generalization in 1915. Einstein realized that the time and space with which we are so directly acquainted by experience can be no other than the fictitious *local* time and space of the moving system—the motion in this case being that of the earth; we have no means of determining, nor can physical science be concerned with, any absolute reckoning of space and time. After this Einstein was led to the identification of mass with energy—another result of far-reaching importance which allows us to know the exact amount of the store of energy so tantalizingly hidden within the atom.

There was a feeling that this theory of relativity for uniform motion must be a particular case of something more general; but observational knowledge seemed to oppose a decisive negative to any extension. It was Einstein again who found the way to the generalization by bringing gravitation into his scheme.

Einstein's general theory of relativity is remarkable alike for the brilliance of conception and the mastery of the mathematical implement required to develop it. The new law of gravitation must be reckoned the first fundamental advance in the subject since the time of Newton. It involves an interaction between gravitation and light, which had indeed been suspected by Newton and almost taken for granted by Laplace, though it dropped out of scientific speculation when the corpuscular theory of light gave way to the undulatory theory. The three crucial astronomical tests of Einstein's theory have all been verified—the motion of perihelion of Mercury, the deflection of light, and the red-shift of the spectral lines. The last-named proved the most difficult to test, but there is now general agreement that it is present in the solar spectrum. More recently Einstein's theory of gravitation has appealed to astronomers not merely as something which they are asked to test, but as a direct aid to the advancement of astronomical research. Invoked to decide the truth of a suspicion of transcendently high density in the "white dwarf" stars,

DR. FREDERICK G. COTTRELL

it has decided that in the companion of Sirius matter is compressed to the almost incredible density of a ton to the cubic inch.

The other direction in which modern physical theory has broken away altogether from the ideas of the nineteenth century is in the quantum theory. Probably no one would claim that he really understands the quantum theory. For such illumination as we do possess we are in great measure indebted to Professor Einstein. In 1905, almost at the same time as he published his first work on relativity, he put forward the famous law of the photo-electric effect, according to which the energy of a single quantum is employed in separating an electron from an atom and endowing it with kinetic energy. This was, perhaps, the first recognition that the development of the new quantum mechanics was not to be tied to classical mechanics by pictures of quasi-mechanical oscillators or other intermediate conceptions, but was to proceed independently on radically different principles. Noteworthy contributions followed on the theory of ionization of material, and on the problem of the specific heats of solids. In 1917 Einstein reached another fundamental result—namely, the general equation connecting absorption and emission coefficients of all kinds. This gives deep insight into the origin of Planck's law of radiation, besides providing new formulae with the widest practical applications.

DR. COTTRELL AND THE RESEARCH CORPORATION

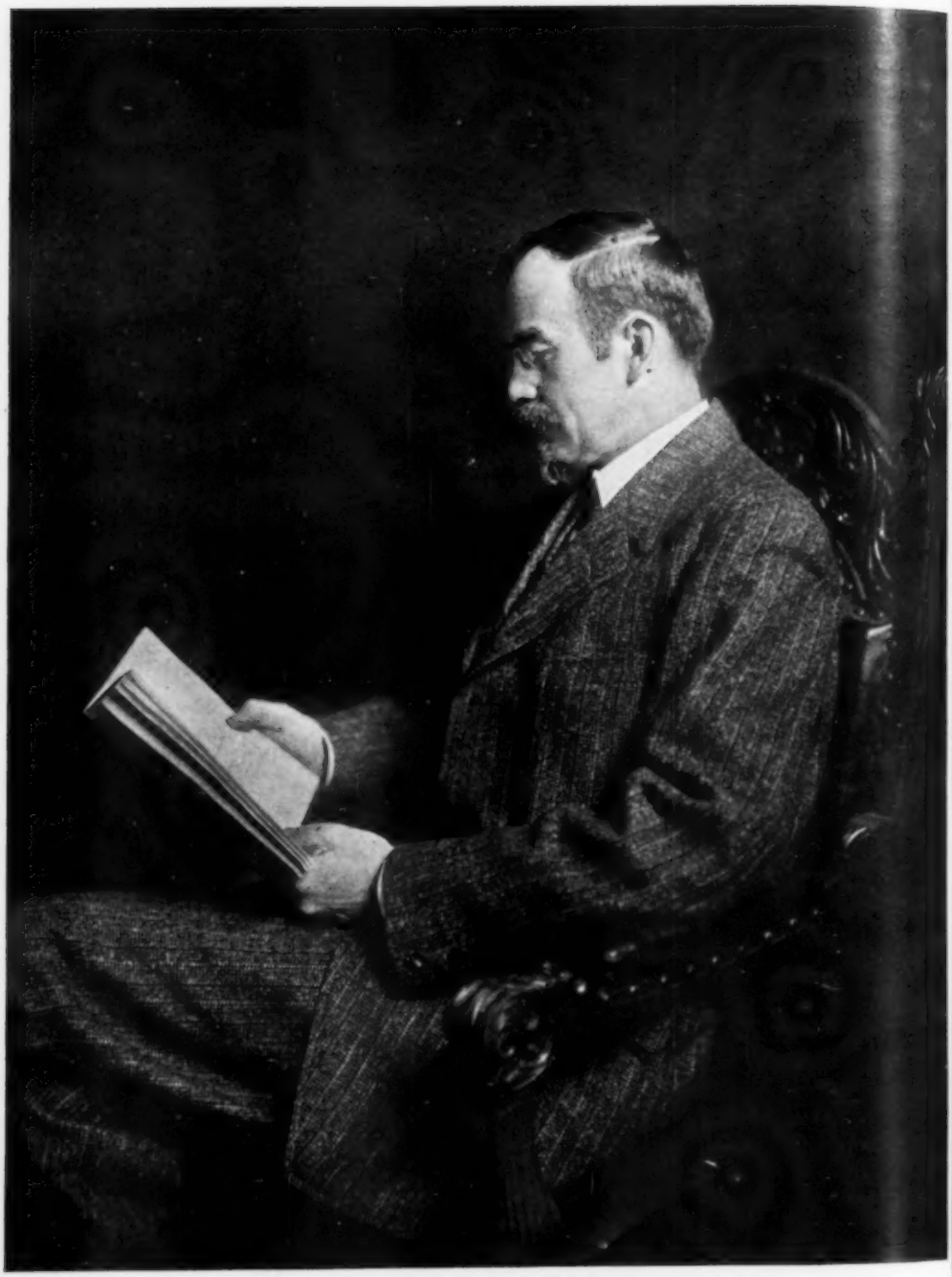
THE Mining and Metallurgical Society of America has awarded its Gold Medal for the year 1924 to Dr. Frederick Gardner Cottrell for "Distinguished service in the development of a method of electrical precipitation of solid and liquid particles from smelter smoke, and in recognition of his public spirit in making a gift of the proceeds of his invention for the support of scientific research."

Electrical precipitation consists of the removal of suspended particles from gases by the aid of electrical discharges. The gas containing the impurities is passed between highly charged electrodes. The particles become electrically charged and are driven to one side by the forces of the electric field.

These processes have now been applied in over eighty-four different industries. The recovered dust or fumes from smelter smoke in many cases is valuable and constitutes a large financial saving. In many other industrial operations where noxious gases, fumes or dusts are given off, the process has been successfully applied, some of the materials precipitated being sulphuric, nitric and hydrochloric acids; arsenic, tar, lead, zinc and other poisonous materials.

The Research Corporation was organized at the instigation of Dr. Cottrell in 1912 when he desired to give his patents for electrical precipitation to the Smithsonian Institution. He hoped that if these patents became valuable, the income from their use would provide revenue to encourage other discoveries. The institution, as Dr. Cottrell soon discovered, was unable to transact business because of charter restrictions, and this led to the organization of the Research Corporation in New York under the cooperation of the Smithsonian establishment. Under the corporation's charter no dividends may be paid on its stock nor may its directors receive fees for serving on the board. It is now fulfilling the purpose for which it was founded and it remains in close association with the Smithsonian Institution.

Subscribers to the capital stock have now been repaid and the stock is held in the treasury of the corporation so that



PROFESSOR JOHN J. ABEL

there are no individual stockholders. The assets have been increased until they now exceed $150,000. The annual business is over $400,000 a year, and the corporation is able out of the returns it receives to defray the operating expenses and to make small grants to the Smithsonian Institution and other worthy causes.

This unique institution is governed by a distinguished board of directors and it has for its president Dr. A. A. Hamerschlag, former president of the Carnegie Institute of Technology at Pittsburgh.

The purpose of the corporation is to lend its aid to the utilization of any invention or discovery which offers sufficient promise of promoting the application of scientific discovery to the industrial arts. This it does by acting as the intermediary between the inventor and the manufacturer, subjecting discoveries and inventions to practical tests and rendering a judicial opinion which can be accepted as trustworthy by manufacturers, bankers and others; by safeguarding the rights of inventors during the preliminary period which determines the commercial success or the adequacy of the organization exploiting the products made under the patents and for this service accepting participation in the royalties and license fees; by receiving special funds, by gift or otherwise, to aid talented inventors in the solution of important industrial and scientific problems; by qualifying as trustees for governmental or institutional control of patents so that private enterprise and capital may secure licenses and exploit new inventions.

The Research Corporation, combining as it does technical and scientific knowledge with commercial facilities, is equipped to play an important and previously unfilled rôle in behalf of inventive genius and industrial progress in the United States.

THE AWARD OF THE PRIZE OF THE RESEARCH CORPORATION TO DR. ABEL

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In all fields of man's activity there are free spirits who stand above the others by the fresh fearlessness of their approach to life. These often are the men who, like Alice, are ready to believe six impossible things before breakfast. And such a one is John J. Abel, whose somewhat prosaic title—professor of pharmacology at the Johns Hopkins Medical School—may not suggest that he and Alice and The White Knight and The Mad Hatter are really cut from the same cloth.

It was recently announced that Dr. Abel has been awarded the Research Corporation prize amounting to $2,500 for "outstanding contributions to the cause of science without profit to himself."

To understand why Professor Abel was given the first award one should, of course, know something of the function of the glands of internal secretion and something about the enormously complex chemical problems involved in isolating the active principle of any one of these glands. This has been Professor Abel's main scientific objective: To isolate from one of the important hormones of the body a chemically pure crystalline substance, a substance of known composition and structure, which can be synthetically prepared, and which, when injected into the body, will reproduce the effects of the natural hormone—effects usually profound in their significance and often altering the appearance and even what might be called the "personality" of the organism.

From the days of the ancients these

small endocrine glands and their secretions have attracted the attention of physicians and natural philosophers. But not until the latter part of the last century did their chief functions and interrelations begin to present themselves. In the four years 1887 to 1891, our knowledge was born of the hypophysis in relation to acromegaly, that bizarre disease in which there is gigantic overgrowth of the long bones of the body; of the thyroid gland and the attendant symptoms of its over and under function; of the parathyroids in relation to tetany; of the pancreas in relation to diabetes, and of the internal secretion of the gonads which at puberty determines the appearance of the secondary sexual characteristics. These observations, often made by clinicians at the bedside, presented problems for the labors of physiologists and chemists. Professor Abel's contributions to the chemistry of epinephrin, now commercially known as "adrenalin," the active principle of the adrenal gland, are the most important in this field.

Latterly he has turned his devoted attention to the chemistry of the secretion of the posterior lobe of the pituitary gland, and it is for this work that he has been so justly awarded. The pituitary gland is a small structure located in the brain which is divided on the basis of embryological and histological differences into an anterior and posterior lobe. These structural differences we know now are associated with differences in function. The anterior lobe presumably elaborates a secretion which has to do with metabolism and growth, particularly skeletal growth, and the deposition of fat. It is, however, the active principle of the much smaller posterior lobe of the gland which Professor Abel has striven to isolate. This secretion contains what is called an oxytocic-pressor principle which has the important function of causing contraction of smooth muscle fibers in the body. Since smooth muscle fibers are widely distributed throughout the vegetative organs, a substance which causes their contraction will naturally produce physiological changes of the greatest consequence to the organism. Some of the characteristic responses to this oxytocic-pressor principle are contraction of the uterus, prolonged rise in arterial pressure with constriction of the peripheral arterioles and capillaries, certain characteristic changes in respiration and a very important antidiuretic action which has been found to be of great practical value in the treatment of an obscure condition known as diabetes insipidus, which is characterized by a harassing and excessive thirst and an enormous fluid elimination. Professor Abel has succeeded in isolating a tartrate of highest purity which, though perhaps not yet a single chemical individual, still is a substance very much purer and more potent than any heretofore prepared.

It does not require professional knowledge of these matters to appreciate the value of such labor, and to realize that here is an effort to inquire into the very essence of the nature of the organism, and to relate anatomical qualities and physiological functions to chemical structure. It is with such knowledge that we can begin to think creatively about the organism as a whole and to modify the course of its development. Only a scientist can realize how heroic are the labors required for such work, and what bold imagination is essential to attempt it. Little surprise, then, that Professor Abel was given the prize.

He has won most of the important academic distinctions, but he had a prize of prizes given him from the start—the quality of perpetual youth in his enthusiasm and patience, the ability to labor prodigiously, but never to tread the treadmill of science. He is always eager, slightly whimsical, generous and untrammeled. He has a Hippocratic devotion to his teachers, Carl Ludwig, Schmiederberg and others, and happily he inspires in his pupils and collaborators the same profound devotion.